U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-292 242

Cost and Economic Impact Assessment for Alternative Levels of the National Ambient Air Quality Standards for Ozone

(U.S.) Environmental Protection Agency, Research Triangle Park, NC

Feb 79

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/5-79-002
February 1979

Air

PB 292242

EPA

Cost and Economic Impact Assessment for Alternative Levels of the National Ambient Air Quality Standards for Ozone

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/5-79-002	2.
3. RECIPIENT'S ACCESSION NO. PB292242	
4. TITLE AND SUBTITLE: Cost and Economic Impact Assessment for Alternative Levels of the National Ambient Air Quality Standard for Ozone	5. REPORT DATE
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): Kenneth H. Lloyd	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Economic Analysis Branch (MD-12) Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, NC 27711	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: U.S. Environmental Protection Agency Office of Air, Noise and Radiation Office of Air Quality Planning and Standards Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED: Final
	14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

This report presents the results of an analysis of the potential impact of feasible changes in the national ambient air quality standard for ozone on national costs of control and the attainment status for various areas of the country. An assessment is made for 90 AQCRs of the control requirements for alternative levels of the standard. For each AQCR this analysis estimates the potential emissions in 1987 and the allowable emissions for attainment of the standard levels. Next, the analysis estimates the potential emission reduction achievable with the Federal Mobile Vehicle Control Program (FMVCP), new and modified source control, application of reasonably available control technology (RACT) on existing stationary sources and further motor vehicle controls through inspection/maintenance programs and transportation control plans. Based on the projected emission reductions, control costs are estimated for applying technology in an attempt to attain alternative standard levels. While the analysis considers each AQCR separately, the results are presented in aggregate form for all 90 AQCRs instead of each individual AQCR.

The analysis does not include a rigorous economic impact assessment on the numerous affected industries or the impact of growth restrictions on the economies of affected urbanized areas. A summary of the impact on several industries for which EPA has conducted economic impact studies is presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Ozone Photochemical Oxidants Ambient Air Quality Standards Hydrocarbon Control Volatile Organic Compounds		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES: 143
	20. SECURITY CLASS *(This page)*	22. PRICE: PC A07 / MF A01

EPA Form 2220-1 (9-73)

EPA-450/5-79-002

Cost and Economic Impact Assessment for Alternative Levels of the National Ambient Air Quality Standard for Ozone

Strategies and Air Standards Division

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

February 1979

PREFACE

In accordance with the provisions of Sections 108 and 109 of the Clean Air Act as amended, the Environmental Protection Agency has conducted a review of the criteria upon which the existing primary and secondary photochemical oxidant standards are based. The Act specifically requires that National Ambient Air Quality Standards be based solely on scientific criteria relating to the level that should be attained to adequately protect public health and welfare. Based on the wording of the Act and its legislative history, EPA interprets the Act as excluding any consideration of the costs of achieving those stanndards or the existence of technology to bring about the needed reductions in emissions. However, in compliance with the requirements of Executive Orders 11821 and 11949 and OMB circular A-107 and with the provisions of the recently issued Executive Order 12044 for rulemaking proceedings which are currently pending, EPA has prepared an assessment of the potential cost and economic impacts associated with efforts to attain the promulgated standard as well as alternative levels of the standard. This document presents the results of this assessment.

The purpose of the analysis contained herein is to estimate the relative ranges of national control costs for alternative levels of the ozone standard. In addition, in order to compare the relative implications of alternative standards, the range in the number of Air Quality Control Regions (AQCRs) which might be expected to attain the alternative standards given various assumptions is also indicated. Because of the many uncertainties in projecting emission levels and air quality levels and in

determining effective control strategies throughout the nation, it is important to fully recognize that the results of the analysis should be viewed only as general guidance which provides an indication of relative differences in the attainment picture and the associated costs between alternative levels of the standard. The analysis cannot be used to precisely determine how many or which specific AQCRs will attain a given ozone standard through particular control strategies. Rather, attainment status and control requirements for attainment will have to be determined for each geographical area based on the unique conditions that are inherent for that area. Likewise, this analysis cannot ascertain with a great degree of precision the costs of control strategies that will be required for all areas of the country to attain alternative standards. Since the actual control costs will be extremely variable, this analysis is useful in only presenting the relative implications for costs between alternative levels of the standard.

TABLE OF CONTENTS

		Page
Chapter 1.0	Introduction and Summary	1-1
1.1	Approach and Methodology	1-1
1.2	Limitations of the Analysis	1-4
1.3	Major Findings	1-9
Chapter 2.0	Baseline Air Quality and Allowable Emission Levels	2-1
2.1	Existing Ambient Air Quality Levels	2-1
2.2	Allowable Emission Levels	2-2
2.3	References	2-8
Chapter 3.0	Projection of Emissions in 1987 and Reasonable Levels of Control Achievable	3-1
3.1	Motor Vehicle Emissions in 1987	3-2
3.2	Projection of Uncontrolled Emissions from Stationary Sources	3-4
3.3	Emission Projections with Controls on New Stationary Sources	3-7
3.4	Reasonably Available Control Measures for Existing Sources	3-8
3.5	Total Emission Reductions and Additional Reduction Required	3-13
3.6	Variation of Results	3-15
3.7	References	3-20
Chapter 4.0	National Costs of Control for Alternative Levels of the Standard	4-1
4.1	Costs for the Federal Motor Vehicle Control Program	4-1
4.2	Costs for New and Modified Stationary Sources	4-2
4.3	Costs of Applying RACT for Stationary Sources	4-4

		Page
4.4	Costs of Applying RACT for Mobile Sources	4-7
4.5	Total Cost of Applying RACT for Alternative Standards	4-9
4.6	Summary of Costs for Identified Measures	4-16
4.7	Estimated Cost of Attainment	4-18
4.8	References	4-23
Chapter 5.0	Economic Impact of Reasonably Available Control Measures on Selected Industries	5-1
5.1	Introduction	5-1
5.2	Petroleum Refining	5-2
5.3	Retail Gasoline Service Stations	5-5
5.4	Gasoline Bulk Plants	5-11
5.5	Automobile Assembly Plants	5-16
5.6	Metal Furniture Industry	5-20
5.7	References	5-25
Appendix A	Ozone Design Values for 90 Air Quality Control Regions	A-1
Appendix B	Mobile Source Emission Factors	B-1
Appendic C	Analysis of Costs for Hydrocarbon Control Measures	C-1
Appendix D	Analysis of Costs for the Federal Motor Vehicle Control Program	D-1
Appendix E	Cost/Effectiveness of Inspection and Maintenance Programs	E-1

1.0 INTRODUCTION AND SUMMARY

The Clean Air Act, as amended in 1977, requires the Administrator of the Environmental Protection Agency to periodically review the basis of the ambient air quality standards. The National Ambient Air Quality Standard for photochemical oxidants has been reviewed and a new form of the standard has been promulgated. As part of this review procedure, this report presents the results of an analysis of the potential impact of feasible changes in the standard on national costs of control and the attainment status for various areas of the country. An analysis of the potential socio-economic impact of the alternative standards has not been conducted for every affected industry and region of the country, although an assessment of the impact of control costs on selected industries is presented to give an indication of the magnitude of the impacts.

1.1 APPROACH AND METHODOLOGY

This report includes an analysis of 90 Air Quality Control Regions (AQCRs) which currently exhibit ambient ozone concentrations in excess of the current photochemcial oxidant standard (.08 ppm hourly average not to be exceeded more than once per year). For each AQCR this analysis estimates potential emissions in 1987 and potential emission reductions achievable with the Federal Motor Vehicle Control Program (FMVCP), new and modified source control, application of reasonably available control technology (RACT) on existing stationary sources and further motor vehicle controls through inspection/maintenance and transportation control plans. Based on the projected emission reductions, control costs are estimated for applying technology in an attempt to attain alternative standard levels. While the analysis considers each AQCR separately, the results are presented in aggregate form for all 90 AQCRs instead of each individual AQCR.

This analysis uses the 1975 emissions inventory from NEDS as the baseline emissions for each of the AQCRs. From this base 1987 emissions are projected based on statutory automotive emissions standards and reasonable ranges of assumptions for growth in vehicle miles traveled (VMT), growth in production for new sources, and retirement rates for existing sources. In addition, assumptions relating to the control of new and modified sources are made in order to determine emissions with only new source and statutory motor vehicle controls.

In order to calculate the emission reduction required, if any, for existing sources to ensure that alternative standard levels are met, the following approach is employed. For each standard level, the maximum allowable emission levels are calculated for each AQCR based on baseline ambient concentrations, 1975 emissions of non-methane hydrocarbons (NMHC), the level of the alternative standard, zero background ozone concentrations in urbanized areas, and assumed relationships between hydrocarbon emissions and ambient ozone concentrations according to alternaitve modeling approaches. These two approaches are the linear rollback model and the Empirical Kinetic Modeling Approach (EKMA).

Once the allowable emissions have been calculated for each AQCR, they are compared with projected 1987 emissions levels taking motor vehicle tailpipe controls and new stationary source controls as the baseline. If additional reductions are required, available control measures are then placed on existing stationary sources that have not been replaced as well as in-use vehicle inspection/maintenance programs or VMT reduction plans for control of mobile source emissions. RACT is assumed only for those specific stationary source categories which have been identified and for which

estimates of control technology and efficiencies have been made. While these sources represent the primary sources of volatile organic compounds (VOC), other sources exist, primarily small solvent evaporation sources, which have not been identified by EPA. As an extension of the analysis, reasonable levels of control for these miscellaneous solvent sources are assumed in order to determine their effect on the results of the analysis. In many instances, control of identified sources and reasonable transportation controls will not result in the required emission reductions, meaning that additional control measures will have to be applied in order to meet the alternative standards. This study does not consider additional control measures, rather only the additional emission reductions needed are indicated.

Once the control measures have been identified, the costs of the measures for the specific sources are then analyzed and estimated. The average cost per ton of emissions controlled is established for general categories of sources and combined with estimates of emission reductions achievable for the 90 AQCRs in order to obtain total annual costs of control in 1987. Costs are included for the FMVCP, new source control, and application of RACT for identifiable sources to the extent required for each of the alternative levels of the standard. For areas that need additional control beyond the identified control measures, a rough estimate of the additional cost to attain the alternative standard is made which will reflect the magnitude of differences in total costs of the alternative levels of the standard. The costs presented in this analysis represent direct annualized costs of control which will be incurred in 1987, when it is assumed that

the control measures will be applied fully to the applicable sources. No estimate of total capital costs is made. In addition, there is no consideration of the secondary costs (i.e., costs beyond those encountered by the source being controlled) or benefits associated with the control measures.

1.2 LIMITATIONS OF THE ANALYSIS

In any analysis of this type many simplifying assumptions have to be made because of the uncertainties that surround the problem. The choice of assumptions, analytical tools, data bases, and approach will profoundly affect the conclusions of the analysis. This analysis attempts to place reasonable ranges on the assumptions in order to estimate the range of national costs for controls necessary to attain a given ozone level. Since the assumptions are so crucial, this section outlines the basic assumptions employed in the analysis and the limitations the choice of these assumptions place upon the results of the analysis. Because of the uncertainties, results using differing assumptions are presented in this analysis.

First of all, this analysis considers 90 AQCRs for which validated data on ambient concentrations exist which indicate violations of the current standard or which contain urbanized areas with populations greater than 200,000 which have been designated non-attainment by EPA. Undoubtedly, there are many other smaller urban areas as well as rural areas which currently also experience violations of the standard. However, these latter areas are not considered in the analysis since validated data have not been compiled for these areas. While this exclusion will understate the costs somewhat, it is not expected to be significant since these areas

probably do not significantly exceed the standard and since the AQCRs which are considered represent well over 60 percent of the nation's population.

In order to calculate the emission reductions required in each of the AQCRs in 1987, assumptions must be made concerning the emissions inventory, baseline air quality values, growth rates, and the modeling technique to be used.

This analysis uses the preliminary 1975 emissions inventory from the NEDS Emission Summary Report, which is the only source of aggregate information on emission data for all 90 AQCRs. No attempt was made to verify the emissions inventory with data from state and local agencies, whose inventories are in some cases at variance with NEDS. Although there are some inconsistencies between NEDS and local inventories, NEDS nonetheless provides a consistent procedure for conducting the inventories throughout each AQCR and is believed to be the best available source of emissions data for national assessments.

Several reasons exist for the differences between NEDS and local inventories. However, the most significant difference is that NEDS includes significant emission contributions from miscellaneous sources of organic solvent applications. Local inventories do not usually include the small miscellaneous sources whose emissions are relatively easy to calculate nationally based on national production statistics but are extremely difficult to calculate on a local basis. Much uncertainty exists as to the exact composition of sources in this ill-defined miscellaneous category. EPA currently has underway an extensive study to better define, classify and locate the sources of solvent evaporation. Conclusive results are not yet available.

The design ozone values used in this analysis represent only an approximation of the ambient ozone concentration that on the average will be exceeded once per year in each AQCR. These values were obtained from an analysis of air quality data for the years 1975 to 1977 using methods described in Guideline for Interpretation of Ozone Air Quality Standards (OAQPS No. 1.2-108). Analysis of air quality data indicates that this value should fall between the third and fourth highest daily averages. These approximate values were derived only for analytical purposes for use in this assessment. In the SIP revisions submitted to EPA, the states will calculate the actual design values which will be used for attainment determinations and for planning purposes.

Growth rates are crucial parameters in determining the overall emission reduction which will be required in 1987. This analysis uses ranges of national average rates of growth in industrial production for various classes of industrial sources as well as ranges of national average rates of growth in vehicle miles traveled. The range brackets the individual growth rates for specific areas. This approach of using national growth rates simplifies the growth projections but introduces some distortions for some local areas. First of all, there is the implicit assumption that every AQCR has the same mix of sources as the nationwide mix on which the average growth rates are based. Secondly, all areas of the country will not experience the same rate of growth. For example, many highly industrialized areas with ozone problems may experience lower rates of growth than less industrialized areas which are attracting new industries. Ideally, for each AQCR, the analysis should use regional growth rates which reflect local economic conditions and the mix of sources in an area. However, results from this analysis show that for standards of .10 ppm or higher, at most four AQCRs change attainment status by shifting from high to low growth rates. This result is not considered significant.

Another variable in the analysis is the modeling techniques employed to estimate the allowable emissions for areas to attain alternative ozone standards. Depending on the technique used, wide variations can result in allowable emission levels and the concomitant reduction in projected emissions that is required. This analysis includes results from application of the linear rollback model as well as the Empirical Kinetic Modeling Approach (EKMA). A judgement as to which modeling approach is more valid or accurate is not made.

The emission reductions that can be achieved with application of various controls measures is still another source of variability in the analysis. The emissions inventory is segmented according to 10 broad categories of industrial sources and three categories of mobile sources. Each of the stationary source categories is composed of many diverse industrial sources which are subject to varying levels of control. Thus, a weighted average control level has to be estimated for each broad category based on the assumed control levels and overall emissions for each individual source category. When this weighted average emission potential is applied to each broad category in each AQCR, it is again assumed that the mix of sources in each AQCR is the same as the nationnwide mix. Thus, this assumption could well affect the results of the analysis for any AQCR.

Furthermore, RACT has not been identified or estimated with any certainty for all sources of hydrocarbons. These sources are primarily in the solvent evaporation category, where the specific sources have not been identified, control technology and efficiency have not been assessed, and whether or not these sources are amenable to control in the first place

has not been determined. Without this information currently available on the remaining sources, further controls are subject to speculation. As an extension of the analysis, this analysis assumes control of these sources in order to determine their impact on control costs and attainment projections.

The approach used in defining control costs is also likely to introduce another area of variability in the analysis. For each of the many sources of VOC, the cost per ton of pollutant removed was determined based on estimated capital and operating costs for "typical" model facilities. Costs for actual facilities are likely to vary considerably, both on low and high sides, due to individual circumstances of the plants. However, the typical plant costs are considered to be representative of the industry as a whole. Once again, to aggregate the control costs for the broad categories of sources, the costs were weighted based on the nationwide mix of sources, which is not representative for all AQCRs.

The range of assumptions made in this analysis in regard to these points appear to be reasonable in terms of estimating costs of control measures for hydrocarbon control. While the intended purpose of this analysis is an estimation of the range of national costs, the approach allows the estimation of the number of AQCRs which will attain alternative levels of the standard. This is only a secondary result which was not considered in the original design of the study. Since the approach of this study can possibly introduce more errors for an individual AQCR,

the estimation of the number of AQCRs which will attain alternative standard levels is particularly sensitive to the choice of assumptions. The estimates of attainment status included in this analysis are only approximate and are valid only for the assumptions and approach used; thus, the estimates should be viewed with full recognition of the limitations of this analysis. Any choice of different assumptions or refinement of the assumptions to a fine-tuned basis was beyond the scope of this study and the attainment numbers are presented only to indicate the relative differences between alternative levels of the ozone standard.

Finally, this analysis does not include a rigorous economic impact assessment on the affected industries or the impact of growth restrictions on the economies of affected urbanized areas. An analysis of the economic impact of the revised standard on the numerous industries affected is not included as part of this analysis. However, EPA has conducted economic impact studies for the major emission sources, though these constitute only a portion of the total number of sources affected. Economic analyses of all affected industries are underway and significant results are expected within two to three years. Furthermore, the Clean Air Act does not permit the consideration of costs and economic impact in the setting of national ambient air quality standards. The incomplete character of the economic analysis for all affected sources and areas does not mitigate EPA's legal burden to promulgate the standard.

1.3 MAJOR FINDINGS

While the results of this analysis are sensitive to the assumptions used, several conclusions are evident which indicate the relative

differences between alternative levels of the standard and the implications for control. This section summarizes the major conclusions of the analysis. Table 1-1 summarizes the results.

1.3.1 Attainment Status for Major AQCRs

Many areas of the country will not be able to attain a .08 ppm level based on the statistical form of the standard by 1987. Based on the results from the linear rollback model, anywhere from 15 to 50 of the major AQCRs in the country will require stationary control measures beyond NSPS and RACT as well as additional transportation control measures in order to approach the standard. The lower estimate reflects a low growth scenario with extensive RACT measures placed on all significant stationary source categories, including the solvent evaporation source categories which have yet to be assessed in detail to determine their amenability to control. On the other hand, the higher estimate is based on a higher growth scenario without control of those solvent evaporation categories which have not been assessed. For a .10 ppm standard level, seven to 20 AQCRs may not achieve the standard by 1987 with the control measures identified in this analysis. Finally, at a .12 ppm standard level, all but five AQCRs could attain the standard under the low growth/high control scenario, while all but 13 could attain under the less optimistic case.

The application of EKMA in the analysis does not lead to as optimistic results since EKMA, with the assumptions used in this analysis, tends to require significantly more control than rollback. The results from EKMA could vary appreciably for any urbanized area depending primarily upon the

Table 1-1. SUMMARY OF ESTIMATED CONTROL COSTS AND ATTAINMENT STATUS IN 1987 FOR VARIOUS LEVELS OF THE OZONE STANDARD

Level of Standard	Modeling Technique	Number of AQCRs Attaining Standard with Identified Control Measures[a,b] (Out of 90)	Range of Costs for Identified Measures[a,b,c] ($ Billions)	Range of Estimated Costs of Attainment[a,c,d] ($ Billions)
.08 ppm	Linear Rollback	44-75	$3.4 - 3.7	$5.0 - 6.5
.10 ppm		70-83	$3.3 - 3.5	$4.5 - 5.0
.12 ppm		77-85	$3.1 - 3.4	$4.0 - 4.5
.14 ppm		82-88	$3.1 - 3.3	$3.5 - 4.0
.08 ppm	EKMA	7	$3.7	$9.0
.10 ppm		40	$3.7	$7.0
.12 ppm		51	$3.6	$6.0
.14 ppm		67	$3.5	$5.5

[a] Ranges under rollback due to range of assumptions in growth rates, degree of control achievable with RACT, and un costs. Only base case results are available for EKMA.

[b] Identified control measures are FMVCP, NSPS, I/M, limited TCP's and two levels of RACT.

[c] Costs are annual control costs in 1987, taking into account net operating and maintenance costs as well as annualized capital charges. Attainment costs rounded to nearest $500 million.

[d] Control measures for total attainment have not been identified. The estimated costs represent the additional emission reduction required multiplied by a lower-bounds cost estimate of $1000 to $1500 per ton controlled.

ratio of ambient non-methane hydrocarbons to nitrogen oxides. Thus, the results from EKMA would be more accurate if NMHC/NOx ratios were available for every AQCR. Based on a typical nationwide ratio of 9.5:1, EKMA predicts that less than 10 AQCRs could attain a .08 ppm standard by 1987. Even at .10 ppm, less than half of the AQCRs could attain the standard even assuming low growth and high control, while at .12 ppm about 40 AQCRs would still be in violation in 1987 without applying further controls.

1.3.2 Implications for Further Control

This analysis confirms that most areas of the country will have to apply extensive control measures in order to attain any of the reasonable levels of the standard. Areas will have to place controls on new and modified sources, aggresively apply RACT to existing sources, institute effective inspection/maintenance programs for in-use vehicles, and implement various degrees of measures to reduce vehicle miles traveled in the urbanized areas. While higher levels of the standard will mean that some areas will come into attainment automatically or will require less emission reduction, most major urbanized areas will not be able to relax control efforts, particularly in the near-term. Because ozone is such a pervasive and intense air pollution problem, any modest relaxation of the standard will not result in any significant changes to existing or planned control strategies for these areas. The major urban areas will need to continue applying all reasonably available control measures.

The results of this analysis also indicate the need for the identification of miscellaneous solvent uses as well as miscellaneous industrial

processes and the assessment of the applicability of control measures for these sources. Current data indicate that these sources represent a significant source of emissions which will need to be controlled if many areas are to attain the alternative levels of the standard.

1.3.3 Costs of Control

As Table 1-1 indicates, the annual cost in 1987 of applying reasonable, identified control measures will range from three to four billion dollars for all levels of the standard under consideration. The cost difference between alternative standards is not as great as might be expected for two basic reasons. First, the vast majority of the total annual costs ($3.0 billion) result from the FMVCP and new source controls, which are assumed to be the same regardless of the level of the standard. Secondly, the RACT control costs do not differ greatly from alternative standards since many areas will have to apply full RACT regardless of the level of the standard.

Since many AQCRs will not attain alternative levels of the standard by applying the reasonably available control measures considered in this analysis, additional control measures will be needed in some areas in order to reduce emissions even further so that the standards can be attained. These measures could include restrictive transportation control measures that significantly reduce vehicle miles traveled in urban areas, control of stationary sources for which RACT has not been identified or defined, tighter controls on new and existing sources other than those achievable with RACT and restrictions on growth. While the costs of such measures have not been estimated, on the whole they are believed to be more costly than current measures.

Even though the costs are not precisely known, it is still useful to estimate the cost of attainment in some manner in order to better indicate the cost differences between alternative standards. To do this, a cost estimate of $1,000 per ton of emissions controlled is assumed for the additional emissions reductions required for each AQCR to attain the alternative standards. Table 1-1 summarizes the estimated costs of total attainment for the alternative standards. The cost differential between standard levels is greater, with the 1987 annual costs for the alternative standards under consideration ranging from $3.5 to $6.5 billion using the results from the linear rollback model. Based on the results from EKMA, total attainment costs could range up to $9.0 billion.

2.0 BASELINE AIR QUALITY AND ALLOWABLE EMISSION LEVELS

This section examines the current ambient levels of air quality in non-attainment areas in order to establish a basis for determining the levels of emission control required to meet alternative levels of the ozone standard. Based on these air quality levels, techniques for establishing allowable emission levels in individual areas are discussed.

2.1 EXISTING AMBIENT AIR QUALITY LEVELS

Many areas of the country are experiencing levels of ozone and oxidant concentrations well above the present standard. In this analysis 90 Air Quality Control Regions (AQCRs) are considered which have validated data that indicate ambient concentrations at or above the present standard of .08 ppm. While other areas of the country may currently violate the standard, validated data were not available for additional AQCRs. Nonetheless, the AQCRs considered contain all the major urbanized areas with populations greater than 200,000.

The baseline ozone design values for the 90 AQCRs are based upon a listing contained in Appendix A. These values reflect an approximation of the ambient concentration that on the average will be exceeded once per year in each AQCR. Using the analytical methods for the statistical form of the ozone NAAQS, these values were obtained from an analysis of data for the years 1975 to 1977.[1] Using three years of data the design value would be expected to fall between the third and fourth highest daily maximum values. In selecting the design values, the fourth highest daily value over a three year period was used, unless the difference between the third and fourth highest values exceeded .01 ppm, in which case the third and fourth highest values were averaged.

These approximate values were derived only for analytical purposes for use in this assessment. In the SIP revisions submitted to EPA, the states will calculate the actual design values which will be used for attainment determinations and for planning purposes. The values will be calculated based on guidance contained in reference 1.

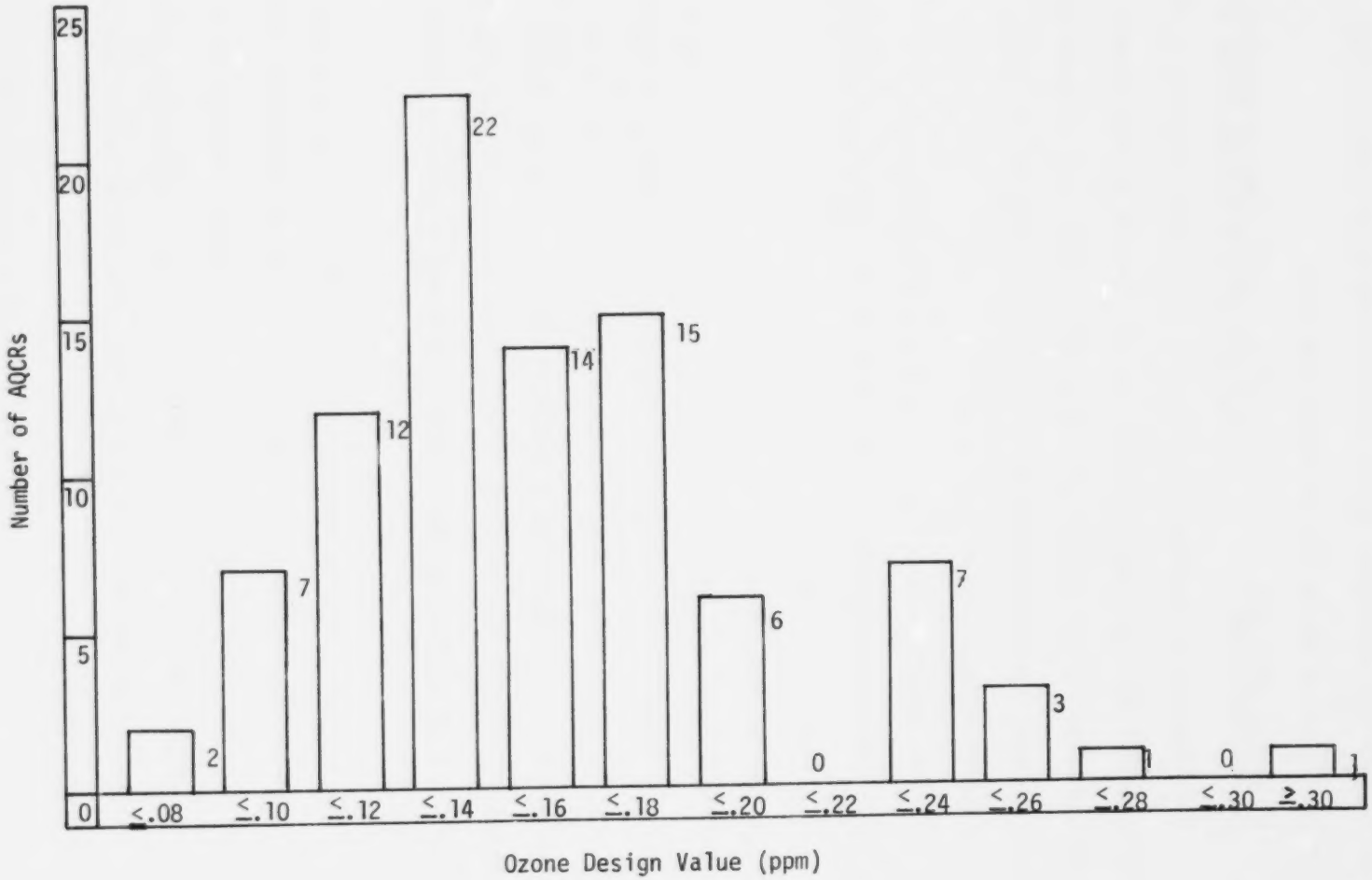
Figure 2-1 shows the distribution of the design air quality values among the 90 AQCRs for which there are data. The adoption of alternative levels of the standard in the range of .08 ppm to .14 ppm would have an immediate effect of bringing many of the AQCRs into compliance, depending on the level of the standard. For a .08 ppm standard, two AQCRs would immediately come into compliance, while for standards at .10 ppm or .12 ppm nine and 21 AQCRs, respectively, would come into compliance. Thirty-two areas have design values above .16 ppm, while only 12 are above .20 ppm.

2.2 ALLOWABLE EMISSION LEVELS

For each alternative level of the standard, the maximum allowable emission levels are calculated for each AQCR based on baseline air quality levels discussed earlier, 1975 total emissions of non-methane hydrocarbons (NMHC), the level of the alternative standard, background ozone levels of zero and assumed relationships between hydrocarbon emissions and ambient ozone concentrations. The maximum allowable emission levels indicate, based on the parameters listed, the emissions which will permit attainment and maintenance of the standard. The 1975 emission levels for each AQCR were obtained from the NEDS Emission Summary Report (NE204), corrected to exclude methane.

Two modeling approaches were used to estimate the allowable emission levels. The first is the linear rollback model which assumes a proportional relationship between hydrocarbon emissions and ambient ozone concentrations,

Figure 2-1. Frequency Distribution of Design Values for 90 Non-Attainment AQCRs[a]



[a]Based on Appendix A, expected second high daily value.

with appropriate adjustment for natuural background levels of ozone. The relationship is given by the following equation:

$$\frac{\text{Allowable emissions}}{\text{Current emissions}} = \frac{\text{(Standard level minus background)}}{\text{(Current ambient concentration minus background}}$$

The alternative approach is the Empirical Kinetic Modeling Approach (EKMA), which employs isopleths based on the results of smog chamber experiments to relate various concentrations of NMHC and nitrogen oxides (NOx) to resulting concentrations of ozone. In employing the model it is necessary to make assumptions as to:

1. the prevailing 6-9 a.m. ratio of ambient NMHC to NOx.,
2. the relative degree to which NMHC and NOx emissions will be controlled, and
3. ozone background levels.

While the NMHC/NOx ratios for various cities will vary widely, it is beyond the scope of this analysis to determine the appropriate ratios for every city. However, best estimates of typical 6-9 a.m. ratios, based on an examination of data from a number of monitoring sites, indicate a median ratio of 9.5:1, which is used in EKMA for purposes of this analysis.[2] In addition, it is assumed that NOx emissions remain constant between 1975 and 1987.

This analysis presents the results from both modeling techniques since both are considered viable approaches for relating ambient ozone to organic compounds and oxides of nitrogen. No judgement is made as to the relative effectiveness or accuracy of the alternative approaches. For a full discussion of the technical basis, uses and limitations of the approaches, consult reference 2.

In essence, EKMA is a rather complex model that has been primarily

validated against data from smog chambers, which represent a simplification of the urban atmosphere. In addition, the absolute positions of the standard isopleths represent an approximation since their position depends upon a number of underlying assumptions concerning meteorological conditions and emission patterns.[2]

Rollback, on the other hand, is a rather simple approach that contains the assumptions that ozone concentrations are proportional to NMHC emissions and that the amount of organic emission controls needed to attain ambient ozone levels is independent of the prevailing NMHC/NOx ratio. However, smog chamber experiments suggest that the lower the ratio, the more effective the hydrocarbon reduction is in reducing the maximum ozone formed. Thus, at very low NMHC/NOx ratios, linear rollback may underestimate the effectiveness of organic controls, while at high ratios estimates may be overly optimistic. Nonetheless, under the range of NMHC/NOx ratios believed to prevail in most U.S. cities, rollback appears to be useful in serving as lower bound for estimates of hydrocarbon controls needed to attain the ozone standard.[2]

Application of the two modeling approaches gives somewhat different results. Table 2-1 illustrates the comparative control levels required for .08 ppm, .10 ppm, and .12 ppm standard levels utilizing both approaches.[2,3] With the exception of cases having very low NMHC/NOx ratios, needed NMHC reductions estimated with rollback are almost always less than those obtained with the standard isopleth version of EKMA.

For the purposes of this analysis, the impact of both transport and and natural background is ignored, so that the background is in essence assumed to be zero. This approach is most feasible for an analysis of this sort and is consistent with the alternatives included with guidance

Table 2-1. COMPARISON OF LINEAR ROLLBACK AND EKMA ESTIMATES OF HC REDUCTIONS NEEDED TO MEET ALTERNATIVE OZONE STANDARD LEVELS

Ozone Design Value (PPM)	Estimated Percent HC Reduction*					
	Standard = .08		Standard = .10		Standard = .12	
	Rollback	EKMA	Rollback	EKMA	Rollback	EKMA
.10	20	38	0	0	0	0
.12	33	53	17	35	0	0
.14	43	63	29	50	14	33
.16	50	65	38	59	25	48
.18	56	69	44	64	33	59
.20	60	71	50	67	40	62
.22	64	72	55	68	45	65
.24	67	73	58	70	50	67
.26	69	74	62	71	54	67
.28	71	74	64	72	57	69
.30	73	75	67	73	60	70
.32	75	76	69	73	62	72
.34	77	77	71	74	65	72

*Assumptions: (1) No Nox Control
(2) EKMA NMHC/NOx Ratio = 9.5:1
(3) Zero Background

issued by EPA to the states for determining hydrocarbon reductions required to achieve the ozone standard.[4] The preferred procedure for estimating transport is to use upwind data collected on the same day as the ozone design value. However, this approach requires suitable monitoring data, which is beyond the scope of this analysis.

In the absence of such data, other procedures must be used. One alternative is to assume that both future and present transport is comprised of only natural background. This procedure is most appropriate in circumstances where the urbanized area is isolated and not likely to be subject to significant transport from other urban areas.

For urban areas that are likely to be impacted by transport from other urban areas, another alternative is to ignore both transport and natural background. Not considering background partially compensates for not being able to directly consider transport from upwind urban areas since background and transport affect control requirements in opposite manners. Consideration of background increases control requirements whereas consideration of transport reduces control requirements. This alternative has been tested and found to result, in most cases, in calculated control requirements which are similar to those in which transport and natural background are considered.[3]

Using both rollback and EKMA, allowable emission levels were calculated for each AQCR. These levels were then compared to projected 1987 baseline emission levels in order to determine the emission reduction that needs to be effected so that all areas will attain the standard level by 1987. These emission projections and control requirements are discussed in the next section.

2.3 REFERENCES FOR CHAPTER 2

1. Environmental Protection Agency, Guideline for Interpretation of Ozone Air Quality Standards, OAQPS No. 1.2-108, Draft.

2. Environmental Protection Agency, Uses, Limitations and Technical Basis of Procedures for Quantifying Relationships Between Photochemical Oxidants and Precursors, EPA-450/2-77-021a, November 1977.

3. Freas, Warren P., Air Management Technology Branch, MDAD, OAQPS, EPA, memorandum to Ken Lloyd entitled "Consideration of Transport and Background in EKMA and Rollback Modeling," September 11, 1978.

4. Rhoades, Richard G., Control Programs Development Division, OAQPS, EPA, memorandum, "Clarification of Attainment/Nonattainment Evaluation Guidance," August 16, 1978.

3.0 PROJECTION OF EMISSIONS IN 1987 AND REASONABLE LEVELS OF CONTROL ACHIEVABLE

This chapter summarizes the emission projections and emission reductions achievable by 1987 for the affected AQCRs. Reasonable ranges of growth rates are applied to 1975 emissions in order to determine 1987 baseline emissions without additional stationary source and mobile source controls other than mobile source standards mandated by the Clean Air Act. Stationary source controls in the form of new source standards and reasonably available control technology (RACT) for existing sources as well as additional mobile source controls in the form of inspection/maintenance programs and transportation control measures are assessed and potential emission reductions quantified. These projected emission reductions are then compared with the baseline 1987 emissions and the calculated maximum allowable emission levels to determine if the available controls result in attainment of the alternative levels of the standards. If the standards are not attained, the additional emission reduction required to reach the allowable emission levels is indicated.

For purposes of this study, RACT is broadly defined as technology readily available for application in categories of sources which will lead to adequate levels of control based solely on technical considerations. Because of unique circumstances with individual sources, the reasonableness of technology for particular sources will be determined by state and local agencies based on technical guidance issued by EPA and depending upon economic and energy feasibility.

Projections are made for each individual AQCR based on its emission inventory and national estimates of growth rates and control efficiency.

National totals of baseline emissions and emission reductions are obtained by summing the totals for the individual AQCRs. A sensitivity analysis is conducted which indicates the variability of the results depending on assumptions concerning growth rates, control levels achievable, and the relative proportion of emissions from source categories.

The assumptions and methodology used in this analysis were chosen specifically to arrive at national emission and cost estimates. For planning in any specific AQCR, more detailed analyses will be required. The procedures to be followed for preparing detailed plans are presented in the document, "Control Strategy Preparation Manual for Photochemical Oxidants."[1]

3.1 MOTOR VEHICLE EMISSIONS IN 1987

Mobile sources include light-duty vehicles, other highway vehicles, and non-highway vehicles (such as aircraft, barges and vessels, railroads and earth moving equipment). The Federal Motor Vehicle Control Program (FMVCP) for highway vehicles will significantly reduce emissions from these sources (see Appendix B). This reduction is counterbalanced by an estimated two to three percent growth per annum in total miles traveled for most areas of the country, though VMT growth in some areas will range from one to six percent.[2] For light-duty vehicles, a total reduction of emissions of 60 to 66 percent is projected by 1987 taking into account both growth and tailpipe controls. Similar reductions for other highway vehicles are expected to be 35 to 45 percent through the FMVCP. These factors are included in the estimated baseline emission projections for 1987 in Table 3-1.

Even though the FMVCP will reduce total mobile source emissions by 40 to 50 percent, this will not be adequate to offset the growth of stationary

Table 3-1. PROJECTED NON-METHANE HYDROCARBON (NMHC) EMISSIONS IN 1987 FOR 90 AQCRs
(Millions of tons/year)

Source Category	1975 Emissions[a]	1987 Emissions With FMVCP and New Source Control
Light-duty vehicles	5.36	1.82 - 2.09
Other highway vehicles	0.76	0.43 - 0.49
Non-highway vehicles	1.22	1.38 - 1.64
Fuel Combustion	0.13	0.15 - 0.17
Chemical manufacturing	0.71	0.67 - 0.73
Petroleum Industries	0.64	0.41 - 0.42
Other Industrial Processes	0.61	0.87 - 0.98
Gasoline Service Stations	0.78	0.58 - 0.60
Petroleum Storage and Transport	0.82	0.61 - 0.63
Industrial Solvent Evaporation	1.47	1.24 - 1.34
Area Solvent Evaporation	5.46	4.36 - 4.65
Solid Waste	0.34	0.27
Miscellaneous	0.49	0.49
TOTAL	18.79	13.28 - 14.50

[a]This emissions inventory represents the sum of emissions for each AQCR obtained from the NEDS Emission Summary Report (NE204), October 1978.

[b]Range results from application of a range of national growth rates discussed in Section 3.2.

source emissions for most areas. Only in the unique circumstance where an area with a high proportion of mobile source emissions is close to the standard will the FMVCP alone permit attainment of the standard. For a .10 ppm standard level, less than 10 of the 81 nonattainment AQCRs would meet the standard in 1987 with the FMVCP alone while at .12 ppm less than 15 of the 69 nonattainment AQCRs would attain the standard. Of course, fewer AQCRs would attain by 1982 with FMVCP alone. Only two of the nonattainment AQCRs could attain a .10 ppm standard and less than 10 additional AQCRs could meet a .12 ppm level.

3.2 PROJECTION OF UNCONTROLLED EMISSIONS FROM STATIONARY SOURCES

In order to determine the total reduction in emissions required in 1987 for each AQCR to achieve the allowable emission level, growth in the current emissions inventory has to be taken into account. In Table 3-1, the 1975 emissions inventory for the 90 AQCRs is indicated, broken down into three mobile source categories and 10 stationary source categories. The inventories for each AQCR come from the NEDS Emission Summary Report (NE 204), current as of October 1978. The breakdown of source categories represent the segmentation of sources contained in the summary report.

For the 90 AQCRs as a whole, emissions from mobile source categories comprise almost 40 percent of the total emissions, mobile source emissions for individual AQCRs range from 15 to 70 percent of the total, though most AQCRs fall in the range between 40 and 60 percent. These categories include light-duty automobiles and trucks, heavy duty trucks, motorcycles, and off-highway vehicles such as vessels and aircraft.

Stationary sources, which include a wide variety of sources, make up the remaining 40-60 percent of the total emissions. While petroleum industries, chemical manufacturing, oil and gas marketing, and industrial surface coating are significant sources, almost half of the stationary source emissions come from a category called area source solvent evaporation. This category includes such sources as solvent metal degreasing, drycleaning, and cutback asphalt paving, but for the most part the actual sources are not well defined. Since much uncertainty exists as to what is exactly included in this category and since the category constitutes such a large proportion of emissions, this report includes a sensitivity analysis whereby 50 percent of the area solvent evaporation emissions are excluded when calculating emission reductions and costs. The results of this analysis are discussed later.

Uncontrolled emissions are projected in 1987 by applying appropriate growth rates for each source category. This analysis employs a range of representative growth rates for the categories which take into account a number of factors. The growth rates are based both on estimates of national growth rates for the affected industries from various sources as well as the range of growth rates that occur in specific AQCRs.[2-5] In the analysis individual growth rates are not used for each AQCR, rather the range of national growth rates is used. Table 3-2 summarizes the range of growth rates used in the analysis.

The growth rates for the industrial source categories are based on estimates of production growth for the affected industries. For the industrial solvent evaporation category, the growth rate reflects a composite rate for all manufacturing categories since solvents are used in a wide range of industries. Projected increases in consumption of gasoline and petroleum

Table 3-2. RANGE OF GROWTH RATES FOR MOBILE AND STATIONARY SOURCES[4]
(Compounded Percent per Year)

	LOW	HIGH
Mobile Sources	2	3
Fuel Combustion	1	2
Chemical Manufacturing	4	6
Petroleum Industries	2	3
Other Industrial Processes	3	4
Gasoline Service Stations	2	3
Petroleum Storage and Transport	2	3
Industrial Solvent Evaporation	3	5
Area Solvent Evaporation	1	2.5
Solid Waste	-2	-2
Miscellaneous	0	0

products serves as the basis for the growth rates for gasoline service stations and petroluem storage and transport. Finally, population growth rates are used as the basis for emission projections for the area solvent evaporation category.[6]

3.3 EMISSION PROJECTIONS WITH CONTROLS ON NEW STATIONARY SOURCES

In non-attainment areas of the country, the recent Clean Air Act Amendments require new and modified stationary sources to achieve the lowest achievable emission reduction (LAER) before the source can be located in an area or modified. Hence, this requirement will result in a significant reduction in emissions from new and modified stationary sources. In order to estimate the reduction in uncontrolled emissions that can be achieved, assumptions as to the efficiency of new source controls have to be made. Since EPA has not yet determined what constitutes LAER for stationary sources, this analysis assumes that new and modified sources will have to achieve a minimum level of control equal to RACT. The underlying assumptions in the determination of RACT control levels will be discussed in the next section. The assumed new source control level for applicable sources are summarized below:

- o Chemical Manufacturing 80%
- o Petroleum Industries 95%
- o Gasoline Service Stations 90%
- o Petroleum Storage and Transport 80%
- o Industrial Solvent Evaporation 80%
- o Area Source Solvent Evaporation 75%

Table 3-1 summarizes the baseline emissions in 1987 assuming statutory motor vehicle controls and minimum controls on new and modified stationary sources. These stationary source estimates include the normal replacement

of existing sources (due to obsolescence) with new, modified, or reconstructed sources that would be subject to control under LAER. As shown in the table, even with growth in emission sources, new source controls on new and modified sources in conjunction with motor vehicle controls will result in an aggregate 20 to 30 percent reduction in hydrocarbon emission levels in the 90 AQCRs by 1987.

3.4 REASONABLY AVAILABLE CONTROL MEASURES FOR EXISTING SOURCES

3.4.1 Estimates of RACT for Stationary Source Categories

For areas that fail to attain the standard with mobile source and new and modified source control, existing sources will be required to install reasonably available control technology (RACT) in order to attempt to attain the standard. RACT will vary among industries and may well vary among sources within an industry. RACT is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economicc feasibility. Since economic feasibility is basically source specific, RACT may vary among sources in an industry. Since this study considers broad categories of sources and does not consider the feasibility of RACT on individual sources, RACT is broadly defined for purposes of this study as technology available for application in categories of sources which will lead to adequate levels of control based solely on technical considerations. In actual practice, the reasonableness of technology for particular sources will be determined by state and local agencies based on technical guidance issued by EPA and depending upon economic and energy feasibility.

EPA is currently developing guideline documents for sources of VOC which will assess the technology available for these sources. Based on studies underway in support of these documents, estimates have been made as to the efficiency of RACT for many industries which constitute major sources of VOC.[7] The industries and individual emission sources are summarized in Table 3-3, which also presents the estimated efficiency of RACT for these sources.

While these sources represent the primary sources of VOC, other sources exist which have not been studied by EPA. These sources are primarily in the solvent evaporation category. In many cases, the specific sources have not been identified and control technology and efficiency have not been assessed, though these sources will be analyzed in detail in the future.

Since the emission inventory for each AQCR from NEDS is segmented according to the 10 broad source categories, the average emission reduction that could be achieved with the application of identified RACT has to be determined for the categories. To do this, it is first necessary to derive the weighted average of the efficiency of RACT for the sources in each category for which RACT has been estimated. This weighted average takes into account the relative contribution to current national emissions and the efficiency of RACT for each source.[7] After this calculation, the total emission reduction in each general source category is determined by multiplying the weighted efficiency of RACT for applicable sources by the percentage of emissions in the general source catetory

Table 3-3. ASSUMED EFFICIENCY IDENTIFIED OF RACT FOR STATIONARY SOURCE CATEGORIES[7,8]

Source Category and Sources Included[a]	Efficiency of RACT (%)
1. Chemical Manufacturing	
o Organic Chemical Manufacturing Industry	
- Process Emissions	90%
- Fugitive Emissions	80%
- Storage and Loading Emissions	90%
- Secondary Emissions	75%
o Pharmaceutical Industry	95%
o Paint Manufacture	90%
o Rubber Industry	75%
Weighted Average of RACT[b]	82%
Current Emissions Affected by RACT[c]	79%
Emission Reduction in Source Category Achievable with RACT	65%
2. Petroleum Industry	
o Gas and Crude Oil Production	90%
o Petroleum Refining	
- Vacuum Jets	100%
- Waste Water Separators	95%
- Miscellaneous Sources	91%
- Process Unit Turnaround	98%
o Natural Gas and Gasoline Plants	96%
Weighted Average of RACT[b]	95%
Current Emissions Affected by RACT[c]	95%
Emission Reduction in Source Category Achievable with RACT	90%
3. Industrial Solvent Evaporation	
Auto and Light Duty Truck Manufacturing	80%
Flatwood Products	80%
Paper Coating	80%
Fabric Coating	80%
Wire Coating	90%
Can Coating	80%
Metal Furniture	85%
Industrial Machinery	80%
Commercial Machinery	80%
Coil Coating	85%
Fabricated Metal Products	80%

Table 3-3. (continued)

Source Category and Sources Included[a]	Efficiency of RACT (%)
Large Appliances	85%
Small Appliances	80%
Weighted Average of RACT[b]	80%
Current Emissions Affected by RACT[c]	75%
Emission Reduction in Source Category Achievable with RACT	60%
4. Area Source Solvent Evaporation	
Dry Cleaning	65%
Vapor Degreasing	55%
Cold Cleaning	50%
Graphic Arts	80%
Adhesives	80%
Cutback Asphalt Paving	100%
Weighted Average	75%
Current Emissions Affected by RACT	39%
Emission Reduction in Source Category Achievable with RACT	30%
5. Petroleum Storage and Transport	
Gasoline and Crude Oil Storage	75%
Gasoline Bulk Terminals	95%
Gasoline Bulk Plants	76%
Weighted Average	80%
Current Emissions Affected by RACT	100%
Emission Reduction in Source Category Achievable with RACT	80%
6. Gasoline Service Stations	
Storage	90%
Refueling	90%
Weighted Average of RACT[b]	90%
Current Emissions Affected by RACT[c]	83%
Emission Reduction in Source Category Achievable with RACT	75%
7. Fuel Combustion[d]	0%
8. Other Industrial Processes[d]	0%
9. Solid Waste[d]	0%
10. Miscellaneous[d]	0%

[a]Sources included are those for which screening studies or guideline documents are being prepared. Many solvent evaporation sources and other industrial processes are not inlcuded because the sources have not been identified or control levels have not been defined.

[b]Represents weighted average of RACT for sources listed based on current national emissions for each category.

[c]Represents the proportion of current national emissions for which RACT can be applied. Excludes emissions from source categories for which RACT control levels have not been identified (based on reference 7) and the residual emissions from sources which have already controlled to the RACT level.

[d]RACT has not been identified for these source categories.

which would be affected by RACT. The emissions affected by RACT include only those sources for which RACT has been identified and which have not already controlled emissions to the RACT level. Thus, this excludes sources not covered by RACT and those already controlled since these latter sources already achieve RACT control.[7,8]

As Table 3-3 indicates, emissions from existing sources can be reduced by 65 percent from the chemical manufacturing industry, 90 percent from the petroleum industry, 80 percent from petroleum storage and transport sources, 75 percent from gasoline service stations, and 60 percent from industrial surface coating operations. However, controls on identified area source solvent evaporation sources will reduce emissions from the total category by only 30 percent, since over half of the emission inventory results from sources which have not been identified and for which control levels have not been estimated.

While the control of identified sources serves as the basis for this analysis, a sensitivity analysis is included which assumes a moderate level of control on the emissions from the unidentified solvent sources and other industrial processes. This assumed level of control amounts to 65 percent of all emissions in each category. Throughout the remainder of the document, the control of identified sources only is termed "identified" RACT while the assumed control of the entire solvent evaporation category as well as other industrial processes is termed "advanced" RACT. For the "advanced" RACT case, the control of emissions from the other source categories remains the same as under "identified" RACT.

3.4.2 Estimates of RACT for Mobile Source Categories

There are measures in addition to tailpipe standards which are available to reduce emissions from mobile sources. Reasonably available measures for mobile vehicles include inspection/maintenance programs as well as traffic reduction measures such as transit improvements, parking management, and traffic management. The emission reduction potential for each of these measures will vary among areas dependent on the applicability of control measures, the relative contribution of each mobile source category, existing traffic patterns, and other factors.

In this study, it is anticipated that an inspection/maintenance program for light-duty autos and trucks could achieve an average reduction of 30 percent of 1987 emissions from the LDV category, with the FMVCP as baseline, though the effectiveness could range from 20 to 50 percent.[9,10] In addition, for purposes of this study, traffic reduction plans are estimated to reduce emissions by two percent compared to the projected baseline in 1987.[11] Hence, total RACT for light duty vehicles is estimated to represent a 32 percent reduction. Similarly, the emissions from other highway vehicles are assumed to be reduced an additional two percent through traffic reduction measures.

As was the case with stationary sources, an "advanced" RACT case is assumed whereby emissions of highway vehicles are reduced by a total of three percent due to traffic control measures.

3.5 TOTAL EMISSION REDUCTIONS AND ADDITIONAL REDUCTION REQUIRED

Table 3-4 summarizes the total emission reduction that can be achieved in the 90 non-attainment AQCRs by 1987. As indicated previously, motor vehicle tailpipe controls in conjunction with new source controls can reduce

Table 3-4. SUMMARY OF EMISSION REDUCTIONS ACHIEVABLE IN 1987 AND ADDITIONAL REDUCTIONS REQUIRED (millions of tons per year)

	Level of Standard (ppm)			
	.08	.10	.12	.14
1975 Emissions	18.79			
1987 Emissions with FMVCP and New Source Control	14.48			
1987 Emissions with FMVCP, New Source Control and Identified RACT	10.67	11.44	12.13	12.61
Approximate Number of AQCRs Attaining Standard with FMVCP, New Source Control, and RACT	44	70	77	82
Additional Emission Reduction Required for all 90 AQCRs to Attain Standard	2.46	1.56	1.03	0.73

Base Case Assumptions:
1. Background equals zero
2. High growth rates from Table 3-2
3. Identified RACT from Table 3-3
4. Linear rollback
5. Emissions inventory from NEDS

1975 emissions by around 23 percent, taking into account growth. The sum of emissions in 1987 in the 90 AQCRs can be reduced by an additional 20 to 25 percent with the application of RACT.

This reduction with RACT does not take into account the control of replaced sources that would also be controlled to the LAER level (see Section 3.3). Considering the control of replaced sources through new source controls, existing stationary source emissions can be reduced from 1975 to 1987 by an average of 40 to 45 percent with identified RACT and 60 to 65 percent with advanced RACT. Of course, the reduction in individual AQCRs will vary depending on the mix of sources and amount of control needed in the area.

Even with full application of RACT to identified source categories, many AQCRs will not be able to attain alternative levels of the standard. Table 3-4 summarizes the attainment status for the AQCRs for the alternative standard levels. As the table indicates, as the standard level increases more AQCRs will come into attainment. Less than 20 AQCRs will be unable to attain standard levels of .10 ppm or greater with identified measures.

Table 3-4 also indicates the total additional emission reductions needed for the non-attaining AQCRs to eventually attain the alternative standard levels. This emission will have to come from currently undefined control measures which will likely be localized in nature.

3.6 VARIATION OF RESULTS

In order to determine the variability of the results with differing input assumptions, a sensitivity analysis was conducted which varied the assumptions regarding growth rates, level of control achievable, proportion of solvent evaporation emissions, and the modeling technique. The results of this analysis are presented in Table 3-5.

Table 3-5. SENSITIVITY OF RESULTS TO VARYING ASSUMPTIONS

Standard Level (ppm)	Low Growth Rates[1]			Advanced RACT[2]			Reduced Solvent Emissions[3]			Combination of Previous Three Columns[4]			EKMA[5]		
	1987 Emissions[6]	AQCRs Attaining[7]	Additional Reduction[8]	1987 Emissions[6]	AQCRs Attaining[7]	Additional Reduction[8]	1987 Emissions[6]	AQCRs Attaining[7]	Additional Reduction[8]	1987 Emissions[6]	AQCRs Attaining[7]	Additional Reduction[8]	1987 Emissions[6]	AQCRs Attaining[7]	Additional Reduction[8]
.08	9.87	61	1.75	9.39	70	1.18	9.03	46	2.08	7.53	75	0.67	10.24	7	5.34
.10	10.68	74	1.09	10.60	80	0.72	9.67	70	1.34	8.50	83	0.55	10.60	40	3.41
.12	11.25	80	0.69	11.62	83	0.52	10.22	77	0.93	9.11	85	0.31	11.00	51	2.61
.14	11.74	85	0.53	12.26	86	0.37	10.60	82	0.67	9.57	88	0.27	11.57	67	1.83

Notes:
1. Base case assumptions from Table 3-4 except for low growth rates from Table 3-2.
2. Base case assumptions except for "advanced" RACT
3. Base case assumptions except that 50% of area source solvent emissions are removed from inventory.
4. Combination of 1, 2, and 3 above.
5. Base case assumptions except for use of EKMA (see Chapter 2 for assumptions).
6. 1987 Emissions (millions of tons per year) with FMVCP, new source control and appropriate RACT.
7. Approximate number of AQCRs attaining standard with FMVCP, new source control, and appropriate RACT (out of 90)
8. Additional emission reduction required for all 90 AQCRs to attain standard (in millions of tons per year)

3.6.1 Growth Rates

Growth rates impact the results of the analysis since a high level of growth for new sources will mean that existing sources will have to reduce emissions to a greater extent to offset the growth in emissions. This analysis employs a range of national growth rates which for the most part emcompass the growth rate projections for individual AQCRs and urbanized areas. The degree of sophistication introduced by using individual growth rates for each AQCR considered in the analysis was not warranted for the level of this analysis, thus national growth rates were used. The base case in the analysis utilizes the high end of the range of the growth estimates for each source category in order to be on the conservative side of emission projections and emission reductions required.

As can be seen from Table 3-5, use of the lower growth rates for the source categories affects the attainment status for only a few AQCRs. While at a .08 ppm standard 17 additional AQCRs are projected to attain the standard based on the low growth rates, the difference is only four and three AQCRs at .10 ppm and .12 ppm respectively. For these seven affected AQCRs, their individual growth rates from OBERS fall within the range of national growth rates used in this analysis, except in a few instances. The population growth estimates, which serve as the basis for projected area source solvent emissions, range from 1.0 to 1.8 percent for these areas, while total manufacturing growth estimates range from 3.4 to 4.3 percent.[4] Likewise, annual VMT growth projections range from 1.4 to 4.6 percent, with four of the areas having rates greater than 2.9 percent.[2]

3.6.2 Control Levels Achievable

While RACT has been identified for a significant number of sources of VOC, there is a sizeable portion of the emissions inventory for which control measures have not been identified. These sources are primarily in the solvent evaporation category, where even specific sources have yet to be fully identified. It is not known what control levels can be achieved from these sources or even if many of the sources are amenable to control in the first place.

Nonetheless, a sensitivity analysis is performed where the emissions from the solvent evaporation categories as well as other industrial processes are reduced by 65 percent through the application of identified and "advanced" RACT by 1987. This assumption makes a big difference for the attainment picture at a standard level of .08 ppm since nearly 60 percent more AQCRs can attain the standard. The differences are not so great as the standard level increases since the increased control makes a difference of ten and six AQCRs at .10 ppm and .12 ppm respectively.

3.6.3 Reduced Solvent Emissions

Since there is much uncertainty surrounding the composition of much of the area source solvent evaporation category, a sensitivity analysis was conducted whereby 50 percent of the area source solvent evaporation emissions was deleted from the inventories of each AQCR. As Table 3-5 shows, such a reduction results in little difference in the attainment picture. Only at a .08 ppm standard do additional AQCRs come into attainment. The reason for no discernable change is that the area source solvent evaporation category still grossly outweighs all other categories even when 50 percent of the

emissions are deleted. Since linear rollback is based on proportional instead of absolute relationships, little difference could be detected in the reduction required for areas to meet the standard unless the category was deleted entirely.

3.6.4 Low Growth Rates, Advanced RACT, and Reduced Solvent Emissions

The most optimistic case from the standpoint of attainment of the standard occurs with low growth rates, advanced RACT, and reduced area source solvent emissions. With this case, nearly all AQCRs could attain all standard levels by 1987. Even at .08 ppm, only 15 AQCRs could not attain the standard, while only seven and five areas could not attain levels of .10 ppm and .12 ppm respectively. Furthermore, the additional emission reduction needed for attainment of the alternative standards is reduced by nearly two-thirds.

3.6.5 Empirical Kinetic Modeling Approach (EKMA)

An alternative modeling approach to linear rollback is EKMA, which was discussed in Chapter 2. A sensitivity analysis was conducted substituting EKMA for rollback in the base case. As can be seen from Table 3-5, the use of EKMA with only general and not area-specific assumptions results in significantly less optimistic results. Only seven AQCRs are projected by this approach to attain a .08 ppm standard, while 40 and 51 areas are projected to attain .10 ppm and .12 ppm levels, respectively. The emission reductions needed to meet the standard levels are significantly greater since the allowable emission levels are around 25 percent lower.

3.7 REFERENCES FOR CHAPTER 3.0

1. U.S. Environmental Protection Agency, Control Strategy Preparation Manual for Photochemical Oxidants, OAQPS Guideline Series No. 1.2-047, January 1977.

2. McCurdy, Thomas, Strategies and Air Standards Division (SASD), OAQPS, EPA, memorandum, "FHWA Projected Increases in Highway Mileage and VMT." April 6, 1978.

3. U.S. Water Resources Council, 1972 OBERS Projections: Economic Activity in the U.S., Volume 1, April 1974.

4. U.S. Department of Commerce, Bureau of Economic Analysis, Projections of Economic Activity for Air Quality Control Regions, August 1973.

5. Data Resources, Inc., (Lexington, Mass.) U.S. Long-Term Review, Winter 1978.

6. U.S. Environmental Protection Agency, Guidelines for Air Quality Maintenance Planning and Analysis, Volume 7: Projecting County Emissions, second edition, January 1975, EPA-450/4-74-008.

7. Walsh, Robert T., Emission Standards and Engineering Division, OAQPS, EPA, Memorandum to Bruce Jordan, "Estimated Reductions in Volatile Organic Compound Emissions Which Could be Effected at Stationary Sources," August 12, 1977.

8. Walsh, Robert T., ESED, OAQPS, EPA, Memorandum, "Current VOC Emission Inventory," November 30, 1977.

9. U.S. Environmental Protection Agency, Mobile Source Emission Factors, EPA-400/9-78-005, March 1978.

10. U.S. Environmental Protection Agency, Appendix N to 40 CFR Part 51: Emission Reductions Achievable Through Inspection and Maintenance of Light Duty Vehicles, Motorcycles, and Light and Heavy Duty Trucks, May 1977.

11. U.S. Environmental Protection Agency, Air Quality Impacts of Transit Improvement, Preferential Lane, and Carpool/Vanpool Programs, EPA-400/2-78-002a, March 1978.

4.0 NATIONAL COSTS OF CONTROL FOR ALTERNATIVE LEVELS OF THE STANDARD

In the previous sections of this report, estimates were made of the amount of non-methane hydrocarbon control needed to meet alternative levels of the ozone standard and control levels achievable with available control measures. A comparison will now be made between alternative levels in terms of the cost of applying available controls for various mobile and stationary sources. The average cost per ton of emissions controlled will be established for general categories of sources and combined with estimates of emission reductions achievable in order to obtain total costs of control. The costs presented represent the costs incurred in the 90 non-attainment AQCRs under consideration in the previous section.

The costs presented in this section represent annual costs of control which will be incurred in 1987, when it is assumed that the control measures will be applied fully to the applicable sources. The annual costs include operating, maintenance and administrative costs as well as annualized capital charges that take into account depreciation and interest costs. No estimates are made of the total capital costs that will result from application of the control measures outlined. In addition, secondary costs and benefits associated with control measures are not estimated.

4.1 COSTS FOR THE FEDERAL MOTOR VEHICLE CONTROL PROGRAM

The Federal Motor Vehicle Control Program (FMVCP) includes tailpipe emission standards for hydrocarbons (HC), carbon monoxide (CO), and nitrogen

oxides (NOx) from motor vehicles. Appendix D presents an analysis of the costs of the program for light duty autos, light duty trucks, heavy duty trucks, motorcycles, and aircraft.[1] Based on the information in the Appendix, Table 4-1 summarizes the total annual costs of the FMVCP in 1987.[2] In that year, the total annual cost of tailpipe controls currently mandated will amount to approximately $5.8 billion.

A judgement has to be made concerning the fraction of the total cost which should be allocated to HC control as opposed to CO and NOx control. Because of the overlap in control among the various system components, it is exceedingly difficult to allowcate costs precisely among pollutants. In this analysis, the costs are allocated equally among all pollutants which are affected by control systems.[1,2] In some instances, the total costs for various components are divided by three when all three pollutants are affected, while in other cases the costs are divided by two since only CO and HC are affected (See Appendix D for details).

Taking into account this allocation approach, the costs for HC control under the FMVCP are presented in Table 4-1. The total annual costs in 1987 amount to approximately $2.2 billion, of which almost 75 percent is due to light duty vehicles. The cost of the FMVCP will be the same irrespective of the level of the standard.

4.2 COSTS FOR NEW AND MODIFIED STATIONARY SOURCES

Costs for new and modified stationary sources result from the costs of controls on new sources as well as replaced existing sources. To estimate new and modified source costs, the emission reductions from these sources, by source category, were obtained from the previous chapter.

TABLE 4-1. FMVCP ANNUAL COST SUMMARY [1,2]
($ BILLIONS)

	Total Cost for All Pollutants [a]	Total Costs Allocated to Hydrocarbons [b]
Light Duty Autos		
Hardware	2.9	1.0
Maintenance	(0.8)	(0.6)
Fuel Consumption	(2.2)	(0.7)
Unleaded Fuel Differential	1.8	0.6
Evaporative Emission Control	0.2	0.2
High Altitude Control	0.4	0.2
Subtotal	2.3	0.7
Light Duty Trucks		
Hardware	1.1	0.4
Maintenance	0	0
Fuel Consumption	0	0
Unleaded Fuel Differential	0.9	0.3
Evaporative Emission Control	0.1	0.1
High Altutude Control	0.2	0.1
Subtotal	2.3	0.9
Heavy Duty Trucks		
Hardware, Maintenance, Fuel Consumption, Unleaded Fuel Differential and Evaporative Emission Control	1.1	0.5
Motorcycles		
Hardware	0.1+	0.1
Aircraft		
Hardware	<0.1	<0.1
	5.8	2.2

[a] Cost of emission standards of 0.41 HC, 3.4 CO, 1.0 NOx

[b] Since the cost of control is difficult to estimate precisely for each of the three pollutants, the costs are allocated equally for common components (i.e., one-third when all pollutants are affected or one-half when just HC and CO are affected).

NOTE: Parentheses indicate net savings.

Next, the emission reductions were multiplied by an average cost per ton of pollutant controlled for each source category. This average cost per ton, the derivation of which will be explained in the next section, was obtained from Table 4-2, which summarizes the average cost of RACT for the source categories. While the costs in Table 4-2 pertain to control of existing sources, these costs were nonetheless used as estimates for new sources in the absence of similar cost data for new sources. It is likely that costs for new sources will be somewhat less than costs for existing sources since controls can be incorporated into new plant construction without retrofit considerations.

Based on this approach, the total national costs of new source control amount to annual costs of over $800 million. This total represents the sum of the costs for all 90 AQCRs based on the high range of growth rates discussed previously. It is assumed that the same level of new source control will be required regardless of the level of the standard.

4.3 COSTS OF APPLYING RACT FOR STATIONARY SOURCES

4.3.1 Cost-effectiveness of Reasonably Available Control Measures

Appendix C presents a discussion of many of the stationary sources of hydrocarbons and the control techniques that are available. An analysis of the costs of these techniques for each source of emissions has been made and summary is also presented in Appendix C. These costs are current as of July 1977.

In order to estimate the average cost per ton of hydrocarbons controlled for the general source categories for which emission projections were made in Chapter 3, the individual sources contained in Appendix C were segmented into the source categories in a manner consistent with the categorization contained in Table 3-3 of the previous chapter. The average cost per ton controlled for each source category represents a weighted average based on the cost per ton and the net reduction in emissions avhievable with RACT for each source. The average costs for the source categories are summarized in Table 4-2.

4.3.2 Analytical Methodology for Estimating Control Levels Needed

For each alternative standard, maximum allowable 1987 emission levels are calculated for each AQCR based on 1975-1977 expected air quality levels, 1975 total emissions of non-methane hydrocarbons, the level of the alternative standard and assumed relationships between NMHC emissions and ambient ozone concentrations using both the linear rollback model and the Empirical Kinetic Modeling Approach (EKMA). The allowable emissions for each AQCR are then compared to the projected 1987 emission levels, based on the national estimates of growth and retirement rates and new source emission levels for each source category over the 12-year interval. If projected emissions are greater than allowable emissions, existing stationary source emissions (i.e., those that have not been replaced) are reduced appropriately due to RACT and RACT costs are computed. The costs are obtained by multiplying the average cost per ton for RACT for each general source category (see Table 4-2) by the emission reduction due to RACT for each category.

TABLE 4-2. AVERAGE RACT CONTROL COSTS

SOURCE	Control Costs ($/Ton)	
	Identified RACT Alone	Identified RACT plus Advanced RACT
Stationary Sources		
Fuel Combustion	-	-
Chemical Manufacturing	100	100
Petroleum Industries	0[a]	0[a]
Other Industrial Processes	-	500
Gasoline Service Stations	275	400
Petroleum Storage and Transport	160	160
Industrial Solvent Evaporation	200	200
Area Source Solvent Evaporation	100	300[b]
Solid Waste	-	-
Miscellaneous	-	-
Transportation Sources		
Light Duty Vehicles		
Inspection/Maintenance	635	635
Transportation Control Measures	1000	1000
Other Highway Vehicles	1000	1000
Non-Highway Vehicles	-	-

[a] Costs are offset by product recovery

[b] Based on a cost of $100/ton for identified sources and $500/ton for additional sources.

If controlled 1987 emissions are less than allowable emissions for alternative standards, the analysis assumes that source categories are partially decontrolled in a manner which minimizes total control costs. This involves applying controls to the source categories in order of the most cost-effective first.

After the costs for each individual AQCR have been determined, the AQCR costs are then summed in order to arrive at national costs. The costs presented are only for those existing sources which have not been replaced by 1987 and does not include the costs of controls on replaced sources, which are included in the new source costs presented earlier.

If additional emission reductions are needed in any of the AQCRs, RACT for mobile sources is then applied. Stationary source controls are considered first since on the whole they are more cost-effective than mobile source measures. While this may not be true for all individual stationary sources, the average cost-effectiveness of controls for the broad stationary source categories is more attractive than the average costs of broad mobile source measures. The cost of mobile source measures will be discussed in a later section.

4.4 COSTS OF APPLYING RACT FOR MOBILE SOURCES

4.4.1 Cost-effectiveness of Reasonably Available Control Measures

Reasonably available control measures for mobile sources include inspection/maintenance programs as well as traffic reduction measures such as transit improvements, parking management and traffic management. Appendix E presents a discussion of the cost and effectiveness of I/M programs, which have a cost of around $635 per ton of HC controlled.

The cost of transportation reduction measures are extremely variable and will depend on the local circumstances. Most traffic reduction measures are interrelated and require a coordinated program in order to be an effective means for reducing hydrocarbon emissions. The maximum emission reductions from transportation measures will result from coordinated measures designed to discourage low occupancy auto use and to encourage transit and carpool use. It is expected that reasonable aspects of these measures, such as carpool programs with preferential highway lanes for high occupancy vehicles, can result in a two percent reduction in light duty vehicle emissions at an approximate cost of $1000 per ton of HC reduced, though this cost could vary from area to area.[3]

4.4.2 Analytical Methodology for Determining Total Cost of Mobile Source RACT

Areas which do not attain the standard by 1982 with FMVCP, new source controls, and identified stationary source RACT will be required to implement I/M programs in urban areas, as well as transportation control measures and additional stationary source controls in order to attain the standard by 1987. To determine the cost and extent of I/M programs, an estimate was made as to the number of areas which would not attain the alternative levels of the standard by 1982 without additional controls past identified stationary source RACT. The number of vehicles in the urbanized areas which would be affected by an I/M program were then estimated. Lacking precise information on the numbers of vehicles in the areas, a rough estimate was made based on population in the area, the national average of vehicles per household, and the average number of people per household. Based on data

from several sources, it is estimated that in urbanized areas there are 450 to 500 vehicles per 1000 population.[4,5,6] This was then compared to the population in the areas to determine the number of vehicles affected.[7] Table 4-3 summarizes the estimated number of areas and vehicles which would be subject to I/M programs.

In order to determine the cost of I/M, the number of vehicles affected is multiplied by an average cost per car of $4.12, which was derived in Appendix E.

In areas that need additional control of mobile sources beyond I/M, emission reductions up to two percent from transportation measures are then included in the emission projections. The tons of hydrocarbons removed are multiplied by the estimated cost of $1000 per ton in order to determine the total cost of the measures.

4.5 TOTAL COST OF APPLYING RACT FOR ALTERNATIVE STANDARDS

4.5.1 Base Case Costs

The total annualized costs in 1987 of applying RACT in the 90 AQCRs are presented in Table 4-4. The costs range from $675 million for a .08 ppm standard to $305 million for a .14 ppm standard. Approximately 68 percent of the total cost of RACT in the 90 AQCRs is due to stationary source controls while about 30% results from I&M. The remaining costs are due to other mobile source controls.

The costs differ for alternative levels of the standard since as the level becomes less stringent more areas can attain the standard without applying full RACT. The difference in costs between alternative standards is not as great as might be expected because many of the larger AQCRs with

TABLE 4-3. ESTIMATED NUMBER OF AQCRs AND VEHICLES AFFECTED BY I/M PROGRAMS [4,5,6,7]

Standard Level (ppm)	Approximate Number of AQCRs Affected	Estimated Number of Vehicles Affected (Millions)
.08	70	43 - 48
.10	45	37 - 41
.12	20	25 - 28
.14	15	19 - 21

TABLE 4-4. ANNUAL CONTROL COSTS IN 1987 FOR APPLYING RACT IN 90 AQCRs FOR ALTERNATIVE STANDARD LEVELS - BASE CASE ($ MILLIONS)

Level of Standard	Identified Stationary Source RACT	Inspection/ Maintenance	TCM	Total RACT Costs
.08 ppm	450	200	25	675
.10 ppm	350	170	15	535
.12 ppm	265	115	10	390
.14 ppm	210	90	5	305

Base Case Assumptions:
1. Background equals zero
2. High growth rates from Table 3-2
3. Identified RACT from Table 3-3
4. Linear rollback
5. Emissions inventory from NEDS

TABLE 4-5. SENSITIVITY OF TOTAL ANNUAL RACT COSTS TO VARYING ASSUMPTIONS ($ MILLIONS)

Level of Standard	Low Growth Rates[1]	Advanced RACT[2]	Reduced Solvent Emissions[3]	Combination of Previous Three[4]	EKMA[5]
.08 ppm	600	1145	605	760	730
.10 ppm	460	850	480	545	675
.12 ppm	340	580	355	390	605
.14 ppm	250	440	275	285	505

NOTES:
1. Base case assumptions from Table 4-4 except for low growth rates from Table 3-2.
2. Base case assumptions except for "advanced" RACT.
3. Base case assumptions except that 50% of area source solvent emissions are removed from inventory.
4. Combination of 1, 2, and 3 above.
5. Base case assumptions except for use of EKMA (see Chapter 2 for assumptions).

the most serious problems are not expected to achieve any of the standard levels. Since these areas have significant levels of emissions and have to apply full RACT regardless of the level of the standard, this results in the same cost of control of the areas.

4.5.2 Sensitivity of Costs to Varying Assumptions

The items discussed in the sensitivity analysis in Chapter 3 also impact upon the costs of RACT since the emission reductions required are different. Table 4-5 presents the total costs of RACT utilizing low growth rates, advanced RACT, reduced solvent emissions and EKMA in the base case analysis.

Low Growth Rates

Lower growth rates used in projecting emissions affect the costs since less control of existing sources is needed to offset the growth in emissions from new sources. For standard levels less than or equal to .12 ppm, the total RACT costs using low growth rates are 10 to 15 percent less than when the higher growth rates are assumed. At a .14 ppm level, the difference is greater than 20 percent.

Advanced RACT

For "advanced" RACT, the costs are naturally greater since more sources are being controlled at a higher cost. The costs range from $440 million at a .14 ppm standard to $1145 million at .08 ppm. In comparison with the identified RACT case, the costs at .08 ppm with advanced RACT are 70 percent greater, but 60 percent more AQCRs (26) are able to attain the standard with the measures. At higher levels of the standard the costs are 45 to 60 percent greater but only four to ten additional AQCRs are able to attain the standard.

Reduced Solvent Evaporation Emissions

The effect of reducing the area source solvent evaporation emissions by 50 percent from the baseline inventory is comparable to the impact of the lower growth rates on the results. Even though the reduction in emissions are significant, the change in costs is not greater because there is not a large reduction resulting in this category in the first place.

Combination of Low Growth Rates, Advanced RACT, and Reduced Solvent Emissions

When the previous three assumptions are combined, the result is that the costs are close to the base case costs. The increase in costs due to advanced RACT are for the most part offset by the decreased costs of low growth rates and reduced solvent emissions. At a level of .08 ppm, the costs of this case are about 15 percent greater, while at .14 ppm the costs are less than 10 percent less.

Empirical Kinetic Modeling Approach (EKMA)

With the general assumptions included in EKMA in this analysis, the use of the approach results in greater emission reductions required for areas to attain alternative standards. This naturally translates into increased costs due to RACT since a higher level of control is required. However, the differences in costs between EKMA and rollback increase significantly as the level of the standard becomes less stringent. Costs based on EKMA are less than 10 percent greater for a .08 ppm standard since most areas are going to have to apply full RACT regardless of the modeling approach. However, the implementation of full RACT allows more areas to attain the standard using rollback than is the case for EKMA.

TABLE 4-6. SUMMARY OF COSTS FOR FMVCP, NEW SOURCE CONTROL, AND RACT ON EXISTING SOURCES - BASE CASE
($ BILLIONS)

Level of Standard	Costs of FMVCP	Costs of New Source Control	Costs of Identified RACT	Total Costs of Identified Measures
.08 ppm	$2.2	$0.8	$0.7	$3.7
.10 ppm	2.2	0.8	0.5	3.5
.12 ppm	2.2	0.8	0.4	3.4
.14 ppm	2.2	0.8	0.3	3.3

NOTE: Costs are rounded to nearest $100 million

As the level of the standard increases, significantly more areas can attain the standard with reduced control under rollback than under EKMA. At .10 ppm the cost difference is almost 25 percent while at .14 ppm the difference is close to 70 percent. The reason for this sizeable cost difference is that under EKMA a majority of the areas will have to apply full RACT regardless of the level of the standard.

4.6 SUMMARY OF COSTS FOR IDENTIFIED CONTROL MEASURES

Table 4-6 summarizes the total costs of the identified control measures discussed thus far. This includes the FMVCP, new source control, and identified RACT measures. As can be seen, the total costs of the measures considered vary relatively little with alternative standards. The costs range from $3.7 billion at the level of .08 ppm to $3.3 billion at .14 ppm.

The reason for the relatively small difference between standard levels, when compared to the total cost magnitude, is twofold. First, the vast majority of the total costs ($3.0 billion) result from the FMVCP and new source controls, which are assumed to be the same regardless of the level of the standard. Secondly, the RACT control costs do not differ greatly from alternative standards since many areas have to apply full RACT regardless of the level of the standard. One point to remember, though, is that these costs do not represent the cost for all 90 AQCRs to attain the standard. AQCRs which fail to attain the alternative standard with the identified control measures will have to apply additional control measures. This will result in a larger difference between the costs associated with the alternative levels of the standard.

TABLE 4-7. SENSITIVITY ANALYSIS FOR TOTAL COSTS OF FMVCP, NEW SOURCE CONTROL AND RACT ($ BILLIONS)

Level of Standard	Low Growth Rates	Advanced RACT	Reduced Solvent Emissions	Combination of Previous Three	EKMA
.08 ppm	$3.4	$4.1	$3.6	$3.6	$3.7
.10 ppm	3.3	3.9	3.5	3.3	3.7
.12 ppm	3.1	3.6	3.4	3.2	3.6
.14 ppm	3.1	3.4	3.3	3.1	3.5

NOTES: 1. Costs are rounded to nearest $100 million.
2. Costs for low growth rates case includes reduced costs.
3. See Table 4-5 for assumptions.

The results of the sensitivity analysis for total costs are presented in Table 4-7. The costs for the various cases vary not more than $400 million from the base case costs for any of the alternative standard levels.

4.7 ESTIMATED COST OF ATTAINMENT

As discussed in Chapter 3, many AQCRs will not attain alternative levels of the standard by applying the control measures outlined in this report. Thus, additional control measures will be needed in some areas in order to reduce emissions even further so that the standards can be attained. These measures could include restrictive transportation control measures that significantly reduce vehicle miles traveled in urban areas, control of stationary sources for which RACT has not been identified or defined, and tighter controls on new and existing sources than those achievable with RACT. The cost-effectiveness of these measures has not been estimated, though on the whole they are believed to be somewhat more costly than current measures that have been defined. While some measures can no doubt be implemented at costs approaching the level of RACT costs identified earlier, many measures are likely to be much more costly. For example, traffic reduction plans are extremely area specific and it is likely that application of such measures could cost up to several thousand dollars per ton of emissions controlled, though by the same token they could cost must less. Likewise, the control of the many solvent evaporation sources that have yet to be identified is likely to be more costly since these sources tend to be relatively small and difficult to control from a technical standpoint. For instance, the cost to control small coin-op drycleaners is estimated to be about $5000 per ton of solvent controlled.[8]

Finally, the cost of applying more stringent controls in place of RACT on new and existing stationary sources is likely to be high due to higher marginal costs of control. Moving to more stringent levels of control for particular sources will involve exponentially higher costs for a relatively small reduction in emissions. For example, the marginal cost of achieving 95 percent control at service stations versus 90 percent control is likely to be greater than $5000 per additional ton removed.[9]

Even though the costs of additional control measures are not known, it is still useful to estimate the cost of attainment in some manner in order to better indicate the cost differences between alternative standards. To do this, a cost-effectiveness estimate of $1,000 per ton controlled is assumed for the additional emissions reductions past "identified" RACT required for each AQCR to attain the alternative standards. While there are likely to be many measures that are more costly than this, it is also quite possible that many measures may be applied at cost levels approaching projected RACT costs discussed earlier in this study. The $1000 per ton figure represents a compromise between the extreme estimates. A sensitivity is also included whereby the cost is increased to $2500 in order to see the impact on the results.

In addition to the assumed cost-effectiveness of additional controls making the cost differences conservative, the differences may also be somewhat understated due to the fact that more stringent levels of the standard are likely to require more sophisticated and extensive, and thus more costly, controls. The approach used in this analysis does not take into account such differences.

TABLE 4-8. ESTIMATED COST FOR ALL 90 AQCRs TO ATTAIN ALTERNATIVE STANDARDS - BASE CASE ($ BILLIONS)

Level of Standard	Total Cost of Identified Measures [a]	Cost of Additional Reduction Required [b]	Total Cost of Attainment
.08 ppm	$3.7	$2.5	$6.2
.10 ppm	3.5	1.6	5.1
.12 ppm	3.4	1.0	4.4
.14 ppm	3.3	0.7	4.0

[a] Identified measures include FMVCP, new source control, and identified RACT.

[b] Emission reduction from Table 3-4 multiplied by $1000/ton, which is a lower bounds estimate.

To determine the total cost of attainment in all 90 AQCRs, the additional emission reduction required (from Table 3-4 for the base case), is multiplied by $1,000 per ton, with the resulting costs added to the costs of the identified control measures. The estimated costs of attainment for the base case are presented in Table 4-8. The costs range from $6.2 billion for a .08 ppm standard to $4.0 billion for .14 ppm. As can be seen, the difference in costs between alternative standards is greater, ranging from a $400 million difference from .12 ppm to .14 ppm to over $1.0 billion from .08 ppm to .10 ppm.

Table 4-9 summarizes the variation in total attainment costs with the various assumptions discussed in previous sections in addition to a different assumption on the cost of the additional emission reduction required past identified measures. In this latter sensitivity, the cost per ton is increased to $2500 per ton in order to indicate the impact on the total costs if these advanced control measures are more costly.

It should be recognized that these advanced control measures will not be implemented in the near-term, rather they are strategies that are likely to be implemented closer to 1987. Prior to 1982, the RACT measures which will be implemented are only those identified stationary source measures. In addition, inspection/maintenance and transportation control measures will not come about until after 1982.

TABLE 4-9. VARIATION IN TOTAL ATTAINMENT COSTS [a]
($ BILLIONS)

Level of Standard	Low Growth Rates [b]	Advanced RACT	Reduced Solvent Emissions	Combination of Previous Three	EKMA	Increased Cost of Additional Reduction [c]
.08 ppm	$5.2	$6.2	$5.8	$4.7	$9.0	$8.7
.10 ppm	4.3	5.1	4.8	4.3	7.1	7.5
.12 ppm	3.8	4.4	4.3	3.9	6.2	5.9
.14 ppm	3.6	4.0	4.0	3.7	5.3	5.1

NOTES: a Total attainment costs include costs from Table 4-7 plus cost of additional reduction required. For columns 1, 3, and 5, the latter cost is obtained by multiplying $1000/ton by emission reduction from Table 3-5. For columns 5 and 6 the emission reduction is multiplied by $1500/ton and $2500/ton, respectively. For column 2, the total cost of attainment is the same as the base case.

b See Table 4-5 for assumptions.

c This case utilized the base case assumptions except that the additional emission reduction is multiplied by $2500/ton instead of $1000/ton.

4.8 REFERENCES FOR CHAPTER 4.0

1. Walsh, Michael P., Office of Mobile Source Air Pollution Control, EPA, Memorandum to Walter C. Barber, "RARG Review of Proposed Revision to the National Ambient Air Quality Standard for Oxidants," December 19, 1978.

2. Personal Communication from Michael P. Walsh, OMSAPC, EPA, to Kenneth H. Lloyd, OAQPS, EPA, December 21, 1978.

3. U.S. Environmental Protection Agency, Air Quality Impacts of Transit Improvements, Preferential Lane, and Carpool/Vanpool Programs, EPA-400/2-78-002a, March 1978.

4. Motor Vehicle Manufacturers Association, Motor Vehicle Facts and Figures '77, Detroit, Michigan.

5. Comsis Corporation, Travel Estimation Procedures for Quick Response to Urban Policy Issues, Washington, D.C.: National Cooperative Highway Research Program, 1977.

6. U.S. Water Resources Council, 1972 OBERS Projections: Economic Activity in the U.S., Volume 5, April 1974.

7. U.S. Department of Commerce, Bureau of Census, Supplemental Report to 1970 Census of Population: Population of Urbanized Areas Established Since the 1970 Census, October 1976.

8. Environmental Protection Agency, Control of Volatile Organic Emissions from Dry Cleaning Operations, Draft, April 1977.

9. Lloyd, Kenneth H., Economic Analysis Branch, OAQPS, EPA, "Cost of Alternative Vapor Recovery Systems at Service Stations," October 20, 1977.

5.0 ECONOMIC IMPACT OF REASONABLY AVAILABLE CONTROL MEASURES ON SELECTED INDUSTRIES

5.1 INTRODUCTION

Control measures to reduce emissions of hydrocarbons and other volatile organic compounds will affect many industries in the U.S. economy. In addition to major industries such as chemical manufacturing, petroleum refining and automobile production, control measures will affect many small industries which use petroleum products or organic solvents in a wide range of applications. Countless industries which produce consumer products use solvents in coating operations, while many industries use solvents in metal and product cleaning. For examples of the industries affected by control measures for hydrocarbons, consult Chapter 3.

An analysis of the economic impact of the revised standard on the numerous industries affected is not possible to complete in the time frame available for analysis. However, EPA has conducted economic impact studies for the major emission sources, though these constitute only a portion of the total number of sources affected. Economic analyses of all affected industries are being initiated and significant results are expected within two to three years. The Clean Air Act does not permit the consideration of costs and economic impact in the setting of health related national ambient air quality standards. The incomplete character of the economic impact analysis for all affected sources does not mitigate EPA's legal burden to promulgate the standard.

Nonetheless, an attempt has been made to give an indication of the economic impact of reasonably available control measures on selected industries. These are industries for which EPA has conducted previous cost or economic studies and for which quantitative or qualitative economic judgements can readily be made.

5.2 PETROLEUM REFINING

5.2.1 Industry Profile

Crude petroluem is refined by 150 companies at 266 refineries located in 40 different states. Production of refined products in the U.S. totalled over 15 million barrels per day in 1976, or 93 percent of nameplate capacity.[1] The industry employs 100,000 workers and is heavily concentrated in the West South Central region of Arkansas, Oklahoma, Texas, and Louisiana. These four states employ 44 percent of all industry workers and supply 43 percent of all refined products. Refineries tend to be concentrated in areas of the country that have oxidant levels that currently exceed the standard.

The petroleum refining industry is somewhat concentrated. The five leading producers own 36.5 percent of all industry capacity; the top ten, 58.5 percent. These leading producers are integrated, major oil companies that engage in exploration, production, refining, distribution, and marketing on the retail level. Other refiners are independent companies that are typically not integrated into more than one other segment of the industry. Prices vary little among companies, although there are occasional examples of price cutting when there is weak demand and an excess of supply.

5.2.2 Costs of Reasonably Available Control Measures

Petroleum refineries are significant sources of volatile organic compound (VOC) emissions. The major point sources of VOC emissions from petroleum refineries are vacuum producing systems (VPS), wastewater separators (WWS), process unit turnarounds (PUT), and leaks from miscellaneous sources such as pumps, compressors, and valves. EPA has analyzed control techniques for these sources, which reduce emissions by 95 to 100 percent. For vacuum producing systems, control can be achieved by venting the emissions to a firebox. Large reductions in emissions can be accomplished for the wastewater separators through covering the separators and forebays. Emissions can be controlled from process unit turnarounds by piping the VOC to a flare or to the fuel gas systems. Finally, emissions from miscellaneous equipment can be substantially controlled by reducing equipment leaks with a monitoring and maintenance program.

Costs of these control measures have also been estimated by EPA based on analysis of a model sized refinery with a throughput of 100,000 barrels per day.[2] Costs for individual refineries will vary considerably due to differences in size, configuration and age of facilities, product mix, and degree of control.

The capital cost for piping for controlling emissions from vacuum producing systems will range from $23,700 to $51,600, depending on whether the system uses surface condensers or contact condensers. However, this control measure should result in an annual savings of $89,000 to $96,700

due to significant credits for the value of the recovered petroleum. For wastewater separators, the capital cost of covers for the facilities will be approximately $62,800, but again due to the value of the recovered petroleum products, a net annual savings of $309,700 should result. The control method for process unit turnarounds has an estimated capital cost of $97,600 for piping and valves. Petroleum product recovery is not as readily recoverable from this control measure, though some refineries currently have facilities for recovering the hydrocarbons. Nonetheless, assuming no recovery of petroleum products, an annualized cost of approximately $25,900 will result. The total capital cost for these three sources will range from $184,000 to $212,000. However, this capital outlay is more than offset by the annual recovered petroleum credits valued at $432,000, which does not include the value of recovered PUT emissions.

Finally, the cost of a monitoring and maintenance program to detect and control equipment leaks has also been estimated.[3] For a model 100,000 barrel per day refinery, the capital cost for monitors will approximate $8,600. The annualized cost of a program, taking into account monitoring and maintenance labor, materials, and capital charges, will be about $103,000. This annualized cost, though, should be offset to some degree by recovery credits of reduced emissions. However, emission reduction factors are not presently quantifiable and thus recovery credits will be extremely variable.

5.2.3 Economic Impact of Control Measures

The economic impact of the control measures outlined in the previous section is expected to be small for several reasons. First, the capital

costs are not large in comparison with the capital cost of a refinery as a whole. The capital cost for a model refinery with a throughput of 100,000 barrels per day is estimated to range from $300 million to $500 million.[4] A capital outlay of $220,000 for the VOC control measures represents an insignificant increase (less than 0.1 percent) in the capital cost of a refinery.

Secondly, the value of recovered petroleum products offsets the capital costs entirely in the first year. Thus, the controls can be justified solely on economic grounds. Lastly, the economic impact should not be large since a significant portion of the industry has already instituted the controls. Twenty-five percent of the industry already controls vacuum producing systems, 80 percent controls wastewater separators, and 40 percent controls process unit turnarounds.[5] Finally, a comprehensive study of the petroleum refining industry indicates that EPA's total air and water pollution regulations will result in only a small impact on this sector.[6]

5.3 RETAIL GASOLINE SERVICE STATIONS

5.3.1 Industry Profile

In 1977, there were approximately 178,000 gasoline stations in the U.S. Over 48,000 service stations have closed in the U.S. since the population peak of 226,000 in 1972. This attrition is expected to continue at least through the early 1980's to a leveling off point of anywhere from 125,000 to 150,000 outlets. The economies of scale of high volume stations and the shift to self-service operations are a prime factor in shrinking retail margins. Consequently, the closure of outlets due to market

rationalization processes will be most severe for those outlets which have relatively low sales volume coupled with high unit expenses.

Major oil companies and regional refiner/marketers supplied over half of the retail service stations in the country with the remaining 43 percent supplied by independent marketers. The traditional retail marketing strategy of major oil companies has been to operate through lessee dealers. These lessee outlets still represent approximately two-thirds of the major oil company stations and almost 50 percent of all stations in the country. The second largest group of outlets are known as open dealers. In these operations, the onsite dealer actually owns or controls the investment in his station where he is physically employed. Open dealers represent over one-third of the retail outlets in the U.S. They are generally branded (i.e., station operating under the brand identification of a major oil company) and supplied either directly by a major oil company or a branded jobber. The other types of retail operations are direct salary outlets and convenience stores, which are low expense, low margin operations which account for less than 25 percent of the total population of gasoline retailers. A summary of the service station market segments is presented in Table 5-1.[7]

Retail service stations dispense an average of about 40,000 gallons per month. In recent years, marketing economics have resulted in a trend toward stations with larger volumes, with small volume operations being marginal operations that have to rely on other parts of the retail trade, such as mechanical work and sales of accessories, in order to remain in business. The high volume stations tend to be mostly direct operations

Table 5-1. 1977 U.S. SERVICE STATION POPULATION

Supplier	Number of Outlets (%) Type of Operation				
	Direct	Lessee	Open Dealer	Convenience Store	Total
Major	6,400 (3.6%)	50,200 (28.2%)	27,800 (15.6%)	700 (0.4%)	85,100 (47.8%)
Regional Refiner	4,100 (2.3%)	9,400 (5.3%)	2,000 (1.1%)	200 (0.1%)	15,700 (8.8%)
Independent Marketer/ Wholesaler - Super "Jobber"	16,600 (9.3%)	4,400 (2.5%)	1,100 (0.6%)	7,700 (4.3%)	29,800 (16.7%)
Small Jobber	5,000 (2.8%)	19,400 (10.9%)	21,900 (12.3%)	1,100 (0.6%)	47,400 (26.6%)
	32,100 (18.0%)	83,400 (46.9%)	52,800 (29.6%)	9,700 (5.4%)	178,000 (100.0%)

which are controlled and operated by the supplier and operate on relatively low margins. Low volume stations, those dispensing less than 25,000 gallons per month, are mostly lessee dealers and open dealers supplied by all classes of suppliers. These low volume stations, which comprise close to 50 percent of the total number of stations, are the segment of the retail industry that is most vulnerable to changes in marketing economics as well as external costs such as vapor recovery costs.

5.3.2 Cost of Reasonably Available Control Measures

Emissions occur from two major sources at service stations - the loading of underground storage tanks (Stage I) and the refueling of motor vehicles (Stage II). For Stage I emissions, vapors can be controlled through the use of a vapor balance system, where vapors are vented by displacement to an intermediate holding area (usually the tank truck) for ultimate disposal or recovery at the bulk terminal or bulk plant. Stage II emissions can be controlled through a variety of systems, the most basic of which is the balance system where vapors from the refueling operation are displaced by means of a tight fitting nozzle and vapor return lines to the underground tank. More elaborate recovery systems create a vacuum where vapors are drawn from the refueling operation, alleviating the need for a tight nozzle fit. Vapors are again displaced to the underground storage tanks, with the excess vapors being incinerated in most cases. There are several variations of this vacuum assist system which are too numerous and involved to discuss here.

Preliminary estimates indicate that vapor balance systems are less costly than vacuum assist systems and provide for between 80 to 90 percent control of the HC emissions. While it may ultimately be necessary to use the vacuum system in specific locations, as yet these locations have not been defined. Consequently,

only the cost of the vapor balance system is considered in this analysis. The capital costs of the balance system varies with the number of dispensers at the station, the number of underground tanks, and the physical layout of the station. For a typical nine dispenser, three island station, the capital costs will approximate $8,800. These costs can range from $4,500 for a two-dispenser station to over $11,000 for a 15-dispenser facility.[8]

Essentially the only operating and maintenance cost associated with the balance system is that for nozzle maintenance since the system does not require any power to operate and there are no moving parts associated with the remainder of the system. Nozzle maintenance requirements will be extremely variable depending on a number of factors. However, it is expected that the nozzle will have to be replaced only once a year or the faceplate and/or boot repaired or replaced no more than twice a year. This would result in an annual maintenance cost of about $60 per nozzle, or about $540 for a nine-nozzle station.

Since the vapor balance system is characterized by a high fixed cost component, the annualized cost per gallon of throughput is naturally highly dependent on the volume of the station and the cost of investment capital for the station. Costs range from about 0.1 cent per gallon for high-volume direct operations to over one cent per gallon for low-volume open dealer. Costs for other low volume outlets range from 0.5 to 0.6 cent per gallon while other medium to high volume outlets have costs ranging from 0.2 to 0.4 cent per gallon.

5.3.3 Economic Impact of Control Measures

The direct economic effect of vapor recovery at service stations is to reinforce the existing economies of scale in gasoline marketing. The competitive position of high volume outlets may be strengthened since their economics will not be significantly affected. On the other hand, low volume outlets which are already marginal operations will have their position eroded even further, even though it is expected that most of these marginal stations will close in the next five years regardless of the requirement of vapor recovery due to unfavorable station economics.

While the costs for the balance system are insignificant to the consumer, the costs are still of appreciable magnitude to the dealer, who typically has a profit margin of one cent or less per gallon on gasoline. Thus, in some instances, vapor recovery costs could entirely wipe out profit margins and in other cases severely reduce the margin by over 50 percent. In addition, some owners of stations may have difficulty obtaining the capital necessary to finance the vapor recovery equipment. Highly leveraged firms may not have the capacity to absorb additional debt and thus could not obtain loans. This aspect is particularly crucial to large independent marketers who typically own anywhere from 20 to 100 stations and hence would have to come up with a sizable sum of investment capital for vapor recovery systems.

It is difficult to segregate the marginal stations which will eventually survive in the marketplace but would have to close with the requirement of vapor recovery. In a study conducted for EPA and OSHA by Arthur D. Little, Inc., an attempt was made to estimate the number of

closures nationwide which would result due to market forces, due to capital availability constraints for vapor recovery investment, and finally due to the impact of the vapor recovery costs on the profitability of stations.[9] The analysis indicated that over 20 percent of the current population could close by 1981 due solely to market forces, with over 75 percent of closures resulting in the lessee dealer segment of the market. Vapor recovery requirements, on the other hand, would result in additional closures representing about six percent of the current population, or just over 10,000 stations nationwide. Around 12 percent of these vapor recovery-induced closures would be in the large independent segment of the market where companies with large numbers of stations would be unable to obtain the required investment to finance vapor recovery systems at all their stations. The remainder of the closures would be open dealers for whom the increased costs would severely reduce or eliminate profit margins and make staying in business unattractive. The closures in this segment of the market would represent about 17 percent of the total open dealer stations.

5.4 GASOLINE BULK PLANTS

5.4.1 Industry Profile

Bulk gasoline loading plants are typically secondary distribution facilities which receive gasoline from bulk terminals by trailer transports, store it in above-ground tanks, and subsequently dispense it via account trucks to local farms, businesses, and service stations. Bulk plants may be owned by a major or independent petroleum refiner, an independent jobber, or an individual operator. Although operation and ownership of bulk plants

include cooperatives and salaried employees, the predominant types are the independent jobber and the commission agent who operates the plant for a larger refiner but owns his own delivery trucks.

Currently there are less than 20,000 bulk plants in operation in the U.S. with almost half having daily throughputs less than 4,000 gallons. This represents a decline of nearly 4,000 stations facilities from the population in 1972. This trend is expected to continue as major oil companies dispose of their many bulk plants as they decline in importance in gasoline distribution and become less profitable. While bulk plants served useful pruposes in years past, their role in the distribuiton chain have declined since more stations are receiving deliveries directly from bulk terminals. Bulk plants are being bypassed since economies of labor and capital can be realized if the transport truck can deliver directly from the terminal to an account, thus reducing the cost of gasoline to the station by an appreciable amount. Another important factor in the decline of bulk plants has been and will continue to be a decline in the customer population served by bulk plants. Small stations and commercial accounts which once depended upon bulk plants are also undergoing a significant attrition in the retail market. Even commercial accounts once served by bulk plants are receiving deliveries directly from terminals. No estimates are available which indicate what the bulk plant population will be in the next five years or once the market rationalization process is completed, though it is expected to be significantly less than the current population.

5.4.2 Cost of Reasonably Available Control Measures

Control of breathing, working and miscellaneous losses resulting from storage and handling of gasoline at bulk plants can be accomplished through submerged fill, balance systems, vapor processing systems and control of truck loading leaks. Vapor processing systems have not been applied to bulk plants, but have been used to recover hydrocarbon vapors at bulk terminals during truck loading.

By changing from top splash loading to submerged fill, vapors generated by loading tank trucks can be reduced by about 58 percent. Submerged fill decreases turbulence, evaporation, and eliminates liquid entrainment. The cost to install submerged fill at the typical plant with three loading arms is less than $1,000. This cost is more than offset by the cost savings that result from the elimination of the generation of vapors during loading.

The vapor balance system operates by transferring vapors displaced from the receiving tank to the tank being loaded. A vapor line between the truck and storage tanks essentially creates a closed system permitting the vapor spaces of the two tanks to balance with each other. In addition, vapor balancing of incoming transport trucks displaces vapors from the storage tanks to truck compartments, with the emissions ultimately being treated at the terminal with a secondary recovery/control system. The vapor balance system can reduce emissions from the bulk plant by around 90 percent.

The capital costs for vapor balance systems at bulk plants will vary depending upon a number of factors, such as the configuration of the plant, age and condition of tanks, and requirements for additional equipment due to local regulations such as fire laws. In areas where these regulations are less restrictive, vapor balance costs are substantially lower. Based

on an analysis of costs from various sources, EPA estimates the capital costs for converting to submerged fill and installing the cheaper vapor balance systems to be around $4,000 for a 4,000 gallon per day (gpd) facility and $5,000 for a 20,000 gpd plant. Except to a minor extent, these costs are not a function of throughput of the bulk plant since the number of tanks is relatively independent of throughput and the number of delivery trucks serviced is small. The annualized costs for these model facilities are offset by a credit for gasoline recovery. The credit, which includes only the savings for the emissions which are not generated in the first place as opposed to the vapors which are returned to the bulk terminal for processing, is naturally a function of throughput. The large bulk plant has a sizeable gasoline recovery credit.

In areas where local regulations prohibit use of the cheaper vapor balance systems, a more complete and expensive balance system will have to be installed. Capital costs for converting to submerged fill and installing the complete balance system would range from about $23,000 for a 4,000 gpd facility to close to $26,000 for a 20,000 gpd plant. The annualized costs for these model facilities amount to around $3,500 for the small plant (or about 0.3 cents per gallon) and about $750 for the large plant (less than 0.1 cent per gallon).

5.4.3 Economic Impact of Control Measures

The economic impact on bulk plant operators due to vapor recovery requirements depends on the system which can be installed at the plant. If the cheaper balance systems can be used, the capital costs are not of such magnitude as to cause a significant impact in the industry.

An economic impact analysis is being conducted by EPA which will quantify the potential impacts which could result from the range of vapor recovery system costs.

The magnitude of the costs for the more expensive balance systems will likely have a more significant impact on bulk plants. A capital outlay of around $23,000 represents a significant investment for small plants. Some sources have reported sales prices for bulk plants that have been sold by major oil companies which range between $45,000 and $65,000. Thus, investment for the expensive vapor balance systems represents one-third to one-half of these transaction prices.[10] A preliminary economic analysis prepared for EPA concludes that bulk plants having throughputs less than 4,000 pgd are either unprofitable or only marginally profitable and could possibly be unable to cope with an expenditure of this magnitude.[11] EPA's current analysis will better determine the extent of the potential impacts of these costs on small bulk plants.

When assessing impacts on bulk plants or potential closures of plants, it is important to consider several points. First, until SIP revisions are submitted, enforcement discretion is being utilized to prevent closures from occurring due to pollution control requirements. Guidance has been developed and provided to the states in developing the SIP revisions. Secondly, not all bulk plants in the country will be affected by vapor recovery regulations. Only bulk plants in

non-attainment areas will be required to install controls. Since bulk plants are concentrated in rural areas, it is likely that a large number of bulk plants would not be required to install vapor recovery systems. Finally, most of the bulk plants that could be closed by vapor recovery requirements are likely to go out of business or dispose of their gasoline operations in the near future due solely to market forces. Hence, vapor recovery requirements could only accelerate closures that will take place even in the absence of such requirements.

5.5 AUTOMOBILE ASSEMBLY PLANTS

5.5.1 Industry Profile

In the model year 1976, over 8.5 million automobiles were sold by U.S. automakers. They represented a significant rebound from 1974 and 1975 sales levels when, respectively, only 7.3 and 6.7 million cars were sold. General Motors and Ford Motor Company dominate the industry as the two companies accounted for 58 and 24 percent of the autos produced in 1976, respectively. The other two major automakers, Chrysler and American Motors, accounted for 16 and three percent, respectively.[12]

There are currently 46 auto assembly plants in the U.S., though this number can vary due to temporary shutdowns and switchovers to light-duty truck assembly. GM has 22 of the plants while Ford has 14. The remainder of the plants are owned by Chrysler and AMC as well as Checker Motors and Volkswagen, which is opening a new plant in Pennsylvania. The locations of these plants are indicated in Table 5-2.[13] Essentially all of the plants are located in non-attainment areas for oxidants.

Table 5-2. U.S. AUTOMOBILE ASSEMBLY PLANTS

Manufacturer	Location
American Motors	Kenosha, Wisconsin
	Toledo, Ohio
Chrysler Corp.	Belvidere, Illinois
	Hamtramck, Michigan
	Detroit, Michigan
	Newark, Delaware
	St. Louis, Missouri
Ford Motor Co.	Atlanta, Georgia
	Chicago, Illinois
	Dearborn, Michigan
	Kansas City, Missouri
	Lorain, Ohio
	Los Angeles, Calif.
	Mahwah, New Jersey
	Metuchen, New Jersey
	St. Louis, Missouri
	San Jose, California
	Twin Cities, Minnesota
	Wayne, Michigan
	Wixom, Michigan
General Motors	Arlington, Texas
	Baltimore, maryland
	Detroit, Michigan
	Doraville, Georgia
	Fairfax, Kansas
	Flint, Michigan
	Framingham, Mass.
	Fremont, California
	Janesville, Wisconsin
	Lakewood, Georgia
	Lansing, Michigan
	Leeds, Missouri
	Linden, New Jersey
	Lordstown, Ohio
	Norwood, Ohio
	Pontiac, Michigan
	St. Louis, Missouri
	South Gate, Calif.
	Tarrytown, New York
	Van Nuys, California
	Willow Run, Michigan
	Wilmington, Delaware
Checker Motors	Kalamazoo, Michigan
Volkswagen	Pennsylvania

The earnings of the automakers sagged in 1974 and 1975 due to reduced sales levels. However, in 1976 earnings expressed as return on equity or return on assets returned to historical levels, though American Motors is still experiencing financial difficulties.

5.5.2 Cost of Reasonably Available Control Measures

For the paint coating of auto bodies at assembly plants, numerous options exist for the control of VOC emissions, with control ranging from 70 to 95 percent. Options potentially consist of process changes, such as electrodeposition (EDP) of the primecoat and water-borne topcoats, and add-on control devices such as carbon adsorption, thermal incineration, and catalytic incineration. For purposes of this study, the most cost-effective control options for prime and top coating were chosen that resulted in at least 80 percent control. Other control options could possibly be chosen in actual existing plants, but this analysis considers only the least costly option, based on costs furnished to EPA by Springborn Laboratories.[14] The following control option was chosen:

- Prime coating: EDP with water-borne dip and solvent guide coat
- Prime and top coat spray booths: Catalytic incineration with primary heat exchange
- Prime and top coat ovens: Catalytic incineration with primary heat exchange.

Add-on controls in addition to EDP are needed for the prime coating operation in order to control emissions from the application of the solvent guide coat.

Costs for these options have been estimated for a "model" auto assembly plant producing 211,200 bodies per year. The capital cost of converting the plant to EDP and adding the control devices is estimated to be about $20.2 million, with $15.7 million resulting from the conversion to EDP, $0.8 million from the prime coat add-on devices, and $3.7 million from the top coat add-on controls.

Annualized costs have also been estimated taking into account operating and maintenance costs of the processes and devices as well as the depreciation and interest charges. Only the incremental O&M costs incurred over the existing base case (solvent-borne prime and top coats with no control) are included in the estimates. However, the entire capital charges of the new processes and devices are included since it is assumed that the existing equipment has no salvage value. Salvage values will vary significantly from plant to plant and thus it is difficult to generalize on an appropriate value. Based on these assumptions, the increased annualized cost of control is estimated to be almost $34 per car.

5.5.3 Economic Impact of Control Measures

EPA is conducting but has not completed a formal study of the economic impact of these controls on the automobile industry. However, tentative conclusions can be drawn.

Currently, about 60 percent of the assembly plants employ EDP to apply prime coats. Since this process change contributes almost half of the annualized cost per body, many of the existing plants will be able to

achieve the required additional control for about $18 per car. In addition, due to the fact that such a large portion of the industry has already moved to EDP for economic and technical reasons the economic impact of such a switch for the remainder of the industry should not be unduly burdensome.

The impact on sales of automobiles is not expected to be significant. Rough estimates based on the Ford Econometric Sales Forecasting Model indicate that a $34 increase in the cost of the average automobile could result in a reduction in sales of 0.2 percent in 1983.[15] This is not a reduction in sales from current levels, but rather a reduction in levels that would otherwise occur in 1983. Such a reduction in foregone sales will have a negligible effect on the return on investment in the industry.

It is important to remember that these general conclusions are based on model plants and average conditions in the industry. Though none of the major firms are expected to experience serious impacts, some individual plants will experience more costly conversions to alternative processes which could affect their viability. A determination of the individual plants which have the potential to be severely impacted has not been determined and is beyond the scope of this analysis.

5.6 METAL FURNITURE INDUSTRY

5.6.1 Industry Profile

The metal furniture industry consists of about 1600 firms employing nearly 100,000 people and producing around $3.4 billion in metal furniture

shipments in 1975.[16] The industry is highly fragmented, including the following categories of products: household metal furniture, office metal furniture, public building furniture, and metal partitions and fixtures. Around 500 firms manufacture household furniture, another 500 manufacture partitions and fixtures, over 400 produce public building furniture, and 200 firms engage in office furniture manufacture.

The industry is characterized by relatively small manufacturers. Whereas single-unit firms, those with one establishment for both manufacturing and administration, account for only 19 percent of the value of shipments for all manufacturing establishments listed by the Census of Manufacturers, such firms account for over double the average for household furniture, public building furniture, and partitions and fixtures. Only the office furniture segment of the market is consistent with the overall industry average. In addition, over 85 percent of all metal furniture establishments employ less than 100 people. In fact, more than 50 percent of the establishments in segments other than office furniture have less than 20 employees, according to the 1972 Census of Manufacturers.[17] The significant number of small firms indicates that no economies of scale are evident which prohibit small manufacturers from competing, especially in regional markets where low labor productivity may be overcome by lower distribution costs.

The manufacturing markets of metal furniture facilities vary. Some plants manufacture furniture to be sold directly to consumers through

retail stores. In contrast, job shops, which produce furniture on a contract basis, apply coatings on many different furniture pieces according to the customer's specifications.

Metal furniture plants are located throughout the U.S. However, the states of Illinois, California, Michigan, New York, and Pennsylvania contain over 50 percent of the establishments in the industry.

5.6.2 Costs of Reasonably Available Control Measures

Measures to reduce volatile organic emissions from metal furniture coating operations consist of process changes as well as exhaust gas treatment with add-on control devices. Applicable process changes include conversion to waterborne coatings, high solids coatings, powder coatings, and electrodeposition (EDP) of waterborne coatings. Add-on control devices include carbon adsorption and incineration. While each of these measures achieves reasonable levels of control, the option chosen by an individual plant will depend upon circumstances specific to the plant.

EPA has estimated costs of the alternative measures on the basis of model plants in order to indicate the relative costs of the alternatives.[18] These models are one-color lines and are sized based on the annual product coverage rates for the coating lines.

For electrostatic spray lines, the most feasible control option appears to be conversion to high solids coatings in order to reduce solvent emissions. The reduction can range from 50 to 90 percent depending upon the type of coating used previously. For a three million square feet per year coating line, the capital cost to convert the line is approximately $15,000, while

for a large plant (48 million square ft/yr) the capital cost will approximate $62,000. These costs represent a five to six percent increase in the investment in the existing line. However, in both cases, the increased capital costs appear to be justified on economic grounds due mainly to the savings in lower applied film cost when compared to conventional solvent coatings. For the larger plant, the cost savings in the first year offset the capital cost entirely, while for the smaller plant the savings represent a return on investment approaching 20 percent.

Conversion to waterborne coatings, appears to be the most feasible option for dip coating lines. Switching to waterborne coatings would entail a capital investment of $3,000 for a smaller facility (seven million square feet/year) and $5,000 for a larger plant (22.5 million square feet/year). These costs represent an increase in investment of two to three percent. There is an increase in operating and maintenance costs due to higher materials costs, resulting in an increase in coating costs of seven percent for the smaller plant and four percent for the larger facility.

5.6.3 Economic Impact of Control Measures

An analysis of the economic impact of these costs on the segments of the metal furniture industry has not been conducted by EPA, thus no definitive conclusions can be drawn. However, it appears from the model plant analysis that conversion to high solids coatings for electrostatic spray lines is justified from an economic standpoint and would be of benefit to that portion of the industry utilizing this coating application method.

On the other hand, conversion to waterborne coating for dip coating lines is more difficult to assess since one has to consider both the capital investment requirements as well as the increased cost of coating on an annual basis. With regard to this latter point, the 1972 Census of Manufacturers indicates that the cost of coating materials comprise 0.8 to 1.4 percent of the value of shipments for metal furniture.[19] An increase of four to seven percent in coating costs resulting from the conversion to EDP will affect the final selling price for the metal furniture by an insignificant amount (less than 0.1 percent). In addition, a capital investment of $3,000 to $5,000 does not appear to be burdensome for most establishments. Some small, marginal facilities may find such an investment level unjustified, but the extent of this is not known.

5.7 REFERENCES FOR CHAPTER 5

1. Energy and Environmental Analysis, Inc. Estimated Cost of Benzene Control for Selected Stationary Sources, February 27, 1978, p. 3

2. Environmental Protection Agency, Control of Refinery Vacuum Producing Systems, Wastewater Separators, and Process Unit Turnarounds, EPA-450/77-025, October 1977, p. 4-10.

3. Environmental Protection Agency, Control of VOC from Petroleum Refinery Equipment, Draft, April 1978, p. 4-7.

4. Energy and Environmental Analysis, p. 10.

5. Environmental Protection Agency, Control of Refinery Vacuum Producing Systems, Wastewater Separators, and Process Unit Turnarounds, EPA-450/77-025, October 1977, p. 5-3.

6. Sobotka and Company, Inc., Economic Impact of EPA's Regulations on the Petroleum Refining Industry, EPA-230/3-76-004, April 1976.

7. Arthur D. Little, Inc., The Economic Impact of Vapor Recovery Regulations On the Service Station Industry, Report prepared for EPA and OSHA, March 1978, p. 6.

8. Lloyd, Kenneth H., "Cost of Alternative Vapor Recovery Systems at Service Stations," Economic Analysis Branch, OAQPS, EPA, October 20, 1977.

9. Arthur D. Little, p. 131.

10. Sobotka and Company, Inc., Bulk Plant Vapor Controls Economic Impact, August 15, 1977, p. 3.

11. Pacific Environmental Services, Inc., Economic Analysis of Vapor Recovery Systems on Small Bulk Plants, September 1976, p. 2-2.

12. Motor Vehicle Manufacturers Association, Motor Vehicle Facts & Figures '77, pp. 8 and 9.

13. Springborn Laboratories, Inc., Study to Support New Source Performance Standards for Automobile and Light-duty Truck Coating, June 1977, EPA-450/3-77-020, p. 35.

14. Ibid, pp. 8-42 and 8-43.

15. Personal communication from Tom Alexander, OPE/EPA to Ken Lloyd OAQPS/EPA, March 13, 1978.

16. Springborn Laboratories, Inc., Study to Support New Source Performance Standards for Surface Coating of Metal Furniture, EPA-450/3-78-006, April 1978, p. 8-1.

17. Springborn, p. 8-15.

18. Environmental Protection Agency, Control of Volatile Organic Emissions from Existing Stationary Sources - Vol. III: Surface Coating of Metal Furniture, December 1977, pp. 3-8 and 3-9.

19. Springborn, p. 8-22.

APPENDIX A

Ozone Design Values for 90 Air Quality Control Regions (Estimated)

OZONE DESIGN VALUES FOR 90 AIR QUALITY CONTROL REGIONS *
(Estimated)

AQCR NUMBER	AQCR NAME	EXPECTED SECOND HIGH DAILY VALUE[a] (PPM)	EXPECTED SECOND HIGH HOURLY VALUE[a] (PPM)
002	Columbus-Phoenix, GA	.15[b]	.15[b]
004	Metropolitan Birmingham	.15[c]	.15
005	Mobile-Pensacola, AL-FL	.15	.16
013	Clark-Mohave, AZ-NV	.12	.15
015	Phoenix-Tucson, AZ	.14[c]	.14
016	Central Arkansas	.13	.13
018	Metropolitan Memphis, AR-MS-TN	.14	.14
022	Shreveport, LA	.14	.15
024	Metropolitan Los Angeles	.38	.38
025	North Central Coat, CA	.11	.12
028	Sacramento Valley, CA	.14	.19
029	San Diego, CA	.24[c]	.24
030	San Francisco, CA	.17	.19
031	San Joaquin Valley, CA	.15	.19
033	Southeast Desert, CA	.25	.25
036	Metropolitan Denver, CO	.17	.17
038	San Isabel, CO	.09	.09
041	Eastern Connecticut	.23	.23
042	Hartford-New Haven-Springfield, CT-MA	.27	.32
043	New Jersey-New York-Connecticut (NJ-NY-CT)	.24	.27
045	Metropolitan Philadelphia NJ-PA	.26	.30
047	National Capital (DC-MD-VA)	.19	.21
048	Central Florida	.10	.10
049	Jacksonville-Brunswick, (FL-GA)	.13	.13
050	Southeast Florida	.12	.13
052	West Central Florida	.14	.14
055	Chattanooga, TN-GA	.11	.11
056	Metropolitan Atlanta, GA	.14	.15
060	State of Hawaii	.06	.08
062	Eastern Washington-Northern Idaho	.08	.08
065	Burlington-Keokut, IA	.11	.12
067	Metropolitan Chicago, IL	.20	.26
069	Metropolitan Quad Cities, IL-IA	.11	.13

070	Metropolitan St. Louis, IL-MO	.23[c]	.23
073	Rockford-Janesville-Beloit, IL-WI	.14	.17
078	Metropolitan Louisville, KY	.17	.22
079	Metropolitan Cincinnati, KY-OH	.17	.20
080	Metropolitan Indianapolis, IN	.17	.17
081	Northeast Indiana	.17[b]	.17[b]
082	South Bend-Elkhart-Benton Harbor, IN-MI	.16[b]	.16[b]
085	Metropolitan Omaha-Council Bluff, IA-NE	.10	.10
092	South Central Iowa	.10	.11
094	Metropolitan Kansas City, KS-MO	.10	.12
099	South Central Kansas	.17[c]	.17
106	Southern Louisiana-Southeast Texas	.19	.19
113	Cumberland-Keyser, MD-WV	.12[c]	.12
115	Metropolitan Baltimore, MD	.23	.25
118	Central Massachusetts	.16	.16
119	Metropolitan Boston, MA	.16	.17
120	Metropolitan Providence, MA-RI	.19	.19
121	Merrimack Valley-Southern New Hampshire, MA-NH	.17	.17
122	Central Michigan	.13	.17
123	Metropolitan Detroit-Port Huron, MI	.18	.23
124	Metropolitan Toledo, MI-OH	.14[c]	.14
125	South Central Michigan	.09	.09
128	Southeast Minnesota-La Crosse, MN-WI	.13	.16
131	Minneapolis-St. Paul, MN	.09	.12
151	Northeast Pennsylvania-Upper Delaware Valley, PA-NJ-DE	.23	.23
152	Albuquerque-Mid Rio Grande, NM	.14[c]	.14
153	El Paso-Las Cruces-Almogordo, NM-TX	.16	.16
158	Central New York	.12	.12
160	Genesse-Finger Lake, NY	.13	.13
161	Hudson Valley, NY	.14	.14
162	Niagara Frontier, NY	.16	.18
167	Charlotte, NC	.14	.17
173	Dayton, OH	.18	.18
174	Greater Metropolitan Cleveland, OH	.19	.19
176	Metropolitan Columbus, OH	.16	.16

178	Northwest Pennsylvania-Youngstown, OH-PA	.19	.21
184	Central Oklahoma	.11	.12
186	Northeastern Oklahoma	.14	.18
193	Portland, OR-WA	.13	.16
195	Central Pennsylvania	.13	.15
196	South Central Pennsylvania	.18	.19
197	Southwest Pennsylvania	.18	.20
199	Charleston, SC	.14[b]	.14[b]
200	Columbia, SC	.14	.15
208	Middle Tennessee	.17	.17
212	Austin-Waco, TX	.12	.13
214	Corpus Christi-Victoria, TX	.11	.14
215	Metropolitan Dallas-Forth Worth, TX	.17	.19
216	Metropolitan Houston-Galveston, TX	.26	.27
217	Metropolitan San Antonio, TX	.15	.16
220	Wasatch Front, UT	.15	.16
223	Hampton Roads, VA	.15	.15
225	State Capital, VA	.17	.20
229	Puget Sound, WA	.13	.14
230	South Central Washington	.15[c]	.15
239	Southeastern Wisconsin	.23	.25
240	Southern Wisconsin	.12	.13

[a] The fourth highest average value over the 3-year period (1975-77) was used unless the difference between the third and fourth highest values exceeded .01 ppm (20 mg/m^3), in which case the average of the third and fourth highest value was used.

[b] Estimated value since no data are available for these areas.

[c] Daily values are not available, thus these values represent the hourly values.

SOURCE: Monitoring and Reports Branch, Monitoring and Data Analysis Division, OAQPS, EPA

*Note: These are only estimates of design values for use in this analysis. Actual values which will be used in the determination of attainment and for planning purposes will be calculated by the state and local agencies based on the guidance issued by EPA.

APPENDIX B
MOBILE SOURCE EMISSION FACTORS

APPENDIX B

MOBILE SOURCE EMISSION FACTORS

This appendix summarizes the mobile source emission factors which serve as the basis for emission projections resulting from the Federal Motor Vehicle Control Program as well as an inspection/maintenance program. Table B-1 presents the non-methane hydrocarbon (NMHC) emission factors for various classes of vehicles for base years 1975 and 1987. The 1987 emission factors reflect the emission standards mandated by the Clean Air Act Amendments of 1977.

In order to estimate the change in mobile source emissions for an area between 1975 and 1987, the following equation is used:

$$\text{1987 Emissions} = \text{1975 Emissions} \times \frac{\text{1987 Emission Factor}}{\text{1975 Emission Factor}} \times (1 + \text{Annual Growth Rate})^{12}$$

Estimates have also been made regarding the effectiveness of an inspection/maintenance program in reducing mobile source emissions through overall improvement in fleet maintenance. Emission factors for light duty vehicles for various I/M scenarios are summarized in Table B-2. As can be seen, the effectiveness of an I/M program depends on the stringency level and the extent of mechanic training. For a 30 to 40 percent stringency level, an I/M program can reduce emissions in 1987 by 25 to 44 percent depending on whether there is mechanic training. For purposes of this study, an emission reduction of 30 percent was assumed to reflect a mid-range of the estimates.

Table B-1. NON-METHANE HYDROCARBON EMISSION FACTORS FOR MOBILE SOURCES[a] (grams/mile)

	1975	1987
Light Duty Vehicles (without I/M)	7.96	1.98
Light Duty Trucks		
0-6000 lbs	8.65	3.30
6000-8500 lbs	12.17	4.71
Heavy Duty Gasoline Trucks	28.66	12.18
Heavy Duty Diesel Trucks	4.33	3.34
Motorcycles	11.01	1.36
All Modes	9.08	2.71

[a] Includes evaporative emissions

Source: Environmental Protection Agency, Office of Transportation and Land Use Policy, Mobile Source Emission Factors, EPA-400/9-78-005, March 1978.

Table B-2. EFFECTIVENESS OF INSPECTION/MAINTENANCE PROGRAMS FOR LIGHT-DUTY VEHICLES (1987 NMHC Emission Factors)

	Base (w/o I/M)	30% Stringency Level*		40% Stringency Level*	
		No Mechanic Training	Mechanic Training	No Mechanic Training	Mechanic Training
Grams/Mile	1.98	1.49	1.19	1.42	1.13
% Reduction from Base	--	25%	40%	28%	43%

*Stringency level is a measure of the rigor of a program based on the estimated fraction of the vehicle population whose emissions would exceed cutpoints for NMHC were no improvements in maintenance habits or quality of maintenance to take place as a result of the program.

Source: Based on Appendix N to 40 CFR Part 51: Emission Reductions Achievable Through Inspection and Maintenance of Light Duty Vehicles, Motorcycles, and Light and Heavy Duty Trucks, May 1977.

APPENDIX C

Analysis of Costs for Hydrocarbon Control Measures

Appendix C

ANALYSIS OF COSTS FOR HYDROCARBON CONTROL MEASURES

C.1 Introduction

This analysis presents the costs for selected hydrocarbon control measures for stationary and mobile sources. The costs are derived from numerous EPA reports and documents and represents the Agency's best estimates of costs as of July, 1977. The sources covered by this analysis are not the only sources of volatile organic emissions, rather they are the sources for which cost information is readily available. Some are described more completely than others, with the extent of coverage depending on the availability of information for each source.

C.2. Costs for Stationary Source Control Measures

Tables C-1 through C-7 summarize the control costs for selected stationary sources. The methodology for estimating costs for most sources involved selecting model facilities of a size or sizes considered typical in the industry. For these model facilities, capital costs for the control equipment were developed which included equipment costs as well as installation costs.

The annualized costs for each model facility include direct operating costs such as labor and materials, maintenance costs, and annualized capital charges. This latter component accounts for depreciation, interest, administrative overhead, property taxes, and insurance. The depreciation and interest are computed by use of a capital recovery factor, the value of which depends on the operating life of the device and the interest rate (in most cases, an annual interest rate of 10 percent has been assumed).

In many instances, the annualized costs also include a credit for product, heat or steam recovery. These credits are substracted from the costs of control so that the annualized costs included in the tables are net costs.

The cost effectiveness of control represents the net annualized costs divided by the annual tons of hydrocarbons removed. While cost effectiveness serves a useful purpose as one factor in comparing control measures, it cannot serve as the only decision-making tool. Cost effectiveness in itself does not give any indication of the economic feasibility of alternatives since it does not take into account the baseline economic or financial conditions of the source or industry. However, such an evaluation was beyond the scope of this study, so that cost effectiveness is the only means available by which to compare control measures. Nonetheless, the limitations should be recognized.

Finally, there are in many cases several control measures available to achieve a certain level of control at the various sources. However, this study considers costs for only one control measure at each control level. In choosing the measure, the assumption is made that a prudent plant manager will choose the lowest cost option on an annualized cost basis. In addition, if a higher level of control can be achieved at a lower annualized cost than a lower level of control, then the latter is not considered to be a viable option. Thus some of the control measures considered may not be as energy efficient as others or recover the end product, but they are still the least cost options and have therefore been chosen for inclusion in the tables.

C.2.1 Oil and Gas Production, Refining, and Storage

Table C-1 presents costs of controlling hydrocarbon emissions from selected sources associated with oil and gas production, petroleum refining, petroleum storage tanks, and natural gas and gasoline processing plants. Exact cost figures are not yet available for these sources, but preliminary consideration of costs indicates that the net costs will be minimal since the costs of control will be, for the most part, offset by appreciable savings from product recovery. In fact, much of the control equipment is already in operation in many plants or fields, indicating that the controls must be justifiable from a cost standpoint in many cases.

C.2.2 Gasoline Handling and Distribution Operations

The costs for controlling hydrocarbon vapor emissions from selected gasoline handling and distribution operations are shown in Table C-2. These operations trace the flow of gasoline and resultant hydrocarbon vapors from the bulk terminal to the bulk plant to the service stations and finally to the refueling of vehicles. As can be seen from the table, relative control costs are much higher at smaller facilities as evidenced by the significantly greater cost effectiveness numbers.

At service stations there are two sources of vapor loss--the underground tanks (Stage I) and vehicle refueling (Stage II). Stage I can be implemented alone at service stations but Stage II cannot since vapors captured during refueling would be lost through the underground tanks that had no control. Thus, costs are presented for Stage I alone and Stages I and II in conjunction. The cost effectiveness numbers for Stages I and II take into account the total amount of vapors collected during the two stages instead of just the incremental cost of controlling Stage II emissions.

Table 1. COSTS OFCONTROL MEASURES FOR OIL AND GAS PRODUCTION, REFINING, AND STORAGE

Source/Affected Operation	Facility Size	Control Efficiency %	Capital Cost ($000)	Annualized Cost ($000)	Cost Effectiveness[1] ($/ton)	Control Measure	Reference
1. Oil and gas production		NA[2]	NA	NA	Min[3]	Detection and maintenance	1, p. 30
2. Petroleum Refineries Miscellaneous Sources		91	NA	NA	Min[3]	- Detection and maintenance - Mechanical Seals - Flare Header System	1, p. 17-18
-Process drain and wastewater separators	62,000 bbl/day	90	NA	NA	(64)[4]	- Floating roof covers	1, p. 20
	200,000 bbl/day	90	NA	NA	(73)	- Floating roof covers - Detection and maintenance	
-Vacuum producing systems	100,000 bbl/day	99	NA	NA	(28)[5]	- Incineration of non-condensables	1, p. 22
-Process unit turnaround		97	NA	NA	Min[3]	- Combust non-condensable vapors	1, p. 25
3. Storage of crude oil and gasoline	250,000 bbl.	97	9.8	2.0[6]	200	- Secondary seal on floating roof tank	1, p. 2
4. Natural gas and natural gasoline processing plants		91	NA	NA	Min[3]	- Covers for oil-water separators - Mechanical seals - Detection and maintenance	1, p. 27

[1]Costs include credit for product recovery, parentheses indicate net savings.

[2]N.A. = not available.

[3]Exact costs for these control measures are not known. However, it is believed that costs are minimal since much of the control equipment is already in operation in many plants or fields. In addition, it is believed that control costs will be offset by savings from product recovery.

[4]These savings pertain only to floating roof covers.

[5]This estimate does not include cost of a condensate receiver for a surface condenser or the cost of covering the barometric hot well.

[6]Emission reduction and hence product recovery and cost-effectiveness of secondary seals over and above primary seals will vary with the wind velocity and the true vapor pressure of the stored product.

Table 2. COSTS OF CONTROL MEASURES FOR SELECTED GASOLINE HANDLING AND DISTRIBUTION OPERATIONS

Source/Affected Operation	Facility Size	Control Efficiency %	Capital Cost ($000)	Annualized Cost[1] ($000)	Cost Effectiveness[1] ($/ton)	Control Measure	Reference
1. Marine Terminals	10^7 bbl/day	95	4000	925[2]	4000	Refrigeration/ absorption	2, p. 142
2. Gasoline Bulk Terminals							
- Top Splash Fill	250,000 gpd	94	195	(8.5)	(24)	Refrigeration	3, p. 4-4
	500,000 gpd	94	281	(38.8)	(55)	Refrigeration	
- Top Submerged Fill and Bottom Fill	250,000 gpd	87	176	19.9	146	Refrigeration	
	500,000 gpd	87	264	22.0	80	Refrigeration	
3. Gasoline Bulk Plants							
- Top Splash Fill	5,000 gpd	58	0.3	(0.7)	(120)	Conversion to top-submerged fill	4, p. 4-3
		93	24.8	5.8	350	Vapor Balance	
	20,000 gpd	58	0.6	(2.9)	(120)	Conversion to top-submerged fill	
		93	57.0	13.3	200	Vapor balance	
- Top-submerged Fill and Bottom Fill	5,000 gpd	93	24.8	5.8	350	Vapor balance	
	20,000 gpd	93	57.0	13.3	200	Vapor balance	
4. Service Stations							
- Underground tanks (Stage I)	3 tanks	93	0.6	(0.2)	(110)	Vapor balance	5
- Underground tanks and vehicle refueling (Stages I and II)	20,000 gpm 3 pumps	90	4.4	0.7	375	Vapor Collection System[3,4]	5
	60,000 gpm 9 pumps	90	8.8	1.5	260		
	120,000 gpm 12 pumps	90	10.9	1.3	120		
5. Gasoline tank trucks		99	N.A.[5]	N.A.	Min.[6]		1, p. 15

[1] Costs include credit for product recovery. Parentheses indicate net savings.

[2] Based on 15 year life and 10% interest for capital recovery factor.

[3] Three technologies (no latch/no flow balance, hybrid aspirator assist, and vacuum assist) appear capable of achieving greater than 90 percent control. While the control capabilities of the three systems are not significantly different under most conditions, costs have been indicated for the hybrid system since these costs range between the costs for the other two systems.

[4] Underground tanks controlled with vapor balance system.

[5] N.A. - not available.

[6] The cost of control will be limited to the cost of installing and maintaining effective seals, connections, and pressure-vacuum valves. This cost is considered minimal when compared to the value of the product recovered.

C2.3 Surface Coating Operations

Table C-3 summarizes the costs for controlling volatile organic emissions from selected surface coating operations. Except for the primer application area and curing oven in automobile and light duty truck assembly plants, which utilize a process change in applying the primer, the control measures considered for these sources are add-on technology to destroy or recover organic compounds from exhaust gases. Thermal incineration, which destroys organic emissions, is considered for all of these processes instead of catalytic incineration because of the variability in the use of the latter. Catalytic incineration is limited to a more restricted range of applications as a result of problems with catalyst deactivation, coating with particulates, poisoning, and type of fuel used (ref. 12, pp. 54-55). Where applicable, though, catalytic units offer the potential of significantly lower fuel consumption and smaller, light-weight units. However, it was beyond the scope of this study to judge the effectiveness of the option in all of the processes considered, so thermal incineration was used since its use is not as limited, even though the costs may be higher.

Costs for incineration include savings from the use of primary heat recovery. Primary heat recovery involves the use of incinerator exhaust to preheat incinerator inlet air instead of using expensive auxiliary fuel. Further heat recovery called secondary heat recovery, is possible in some applications where incinerator exhaust from the primary heat recovery stage (or from the incinerator directly if there is no primary heat recovery) replaces energy usage elsewhere in the plant. This energy can be used for

Table 3. COSTS OF CONTROL MEASURES FOR SELECTED SURFACE COATING OPERATIONS

Source/Affected Operation	Facility Size	Control Efficiency %	Capital Cost ($000)	Annualized Cost[1] ($000)	Cost Effectiveness[1] ($/ton)	Control Measure	Reference
1. Automobile and light duty truck assembly							
- Primer application area	123×10^3 scfm	93%	5000[2]	600	1140	Electrophoretic application of primer	6, p. 6-21
- Primer curing oven	1.6×10^3 scfm						
- Topcoat application area	248×10^3 scfm	85%	2700	990[3]	1110	· Carbon adsorption	6, p. 6-28
		95%	1500	2900[4]	2910	· Thermal incineration[4]	6, p. 6-32
	1815×10^3 scfm	85%	19,600	7260[3]	1100	· Carbon adsorption	6, p. 6-28
		95%	11,000	21,300[4]	2900	· Thermal incineration	6, p. 6-32
- Topcoat curing oven	3.4×10^3 scfm	95%	88	53[4]	335	· Thermal incineration	6, p. 6-34
	25×10^3 scfm	95%	280	244[4]	205	· Thermal incineration	6, p. 6-34
2. Can Coating	5.0×10^3 scfm	90%	162	42[3]	215	· Carbon adsorption	6, p. 2-31
		95%	N.A.	53[4]	160	· Thermal incineration	6, p. 2-23
	15×10^3 scfm	90%	302	90[3]	105	· Carbon adsorption	6, p. 2-31
		95%	N.A.	100[4]	100	· Thermal incineration	6, p. 2-23
3. Coil Coating							
- Coaters, ovens, quench areas	15×10^3 scfm	95%	N.A.	74[4]	95	· Thermal incineration	6, p. 3-18
4. Fabric Coating							
- Application area and drying oven	15×10^3 scfm	90%	320	60[3]	35	· Carbon adsorption	6, p. 4-17
		95%	150	66[4]	35	· Thermal incineration	6, p. 4-14
5. Paper coating	15×10^3 scfm	90%	320	60[3]	40	· Carbon adsorption	6, p. 5-25
		95%	150	66[4]	35	· Thermal incineration	6, p. 5-22
6. Magnet wire coating	15×10^3 scfm	95%	N.A.	74[4]	95	· Thermal incineration	6, p. 3-18 1, p. 68
7. Large appliances							
	1950 hr/yr	85%	530	(224)	(840)	EDP Prime Coating	13, p. 3-10, 3-14
	5760 hr/yr	85%	530	(891)	(1120)	Waterborne Top Coating	
8. Metal Furniture							
Spray Coating	278×10^3 sq.m/yr	86%	15	(3)	(158)	Higher solids coating	14, pp. 3-8 3-9, 3-12
	4.5×10^6 sq.m/yr	86%	62	(69)	(226)		
Dip Coating	650×10^3 sq.m/yr	80%	3	11	440	Waterborne coating	
	2.1×10^6 sq.m/yr	80%	5	18	162		

[1] Costs include credit for product or heat recovery. Parentheses indicate net savings.

[2] The capital cost depends on the age of the existing prime line. A value in the middle of the range of the costs has been chosen.

[3] Includes solvent recovery credited as fuel value of solvent.

[4] Includes credit for primary heat recovery.

process heat requirements or for plant heating. However, credits for secondary heat recovery have not been included in this analysis since the amount of energy that a plant can recover and use depends on the individual circumstances of the plant (ref. 12, p. 45).

Carbon adsorption, the other add-on technology considered, separates and recovers organic vapors from the exhaust stream but is not as efficient as incineration in general. The annualized costs for this control measure includes a credit for the recovered solvent at its fuel value, which is lower than the solvent's market value. Nonetheless, the market value of the recovered solvent has not been used in general because reuse of the solvent may not be feasible due to mixture of solvents or breakdown of single solvents. Distillation is possible, but the complexity and cost are so variable that it is difficult to generalize (ref. 12, p. 32). Thus, the fuel value of the solvent has been used as a conservative figure.

C.2.4 Graphic Arts Processes

Costs of control measures for selected graphic arts processes are tabulated in Table C-4. Once again, the techniques considered are incineration with primary heat recovery and carbon adsorption with solvent recovery credited at the fuel value of the solvent.

C.2.5 Degreasing, Dry Cleaning, and Cutback Asphalt Paving

Table C-5 presents control costs for selected sources of evaporative emissions of organic vapors. One such category of sources is organic solvent metal cleaning, which includes cold cleaners, open top vapor degreasers, and conveyorized degreasers. Dry cleaning operations include neighborhood and industrial petroleum solvent plants as well as coin-op,

Table 4. COSTS OF CONTROL MEASURES FOR SELECTED GRAPHIC ARTS PROCESSES

Source/Affected Operation	Facility Size	Control Efficiency %	Capital Cost ($000)	Annualized Cost[1] ($000)	Cost Effectiveness ($/ton)	Control Measure	Reference
1. Webb Offset Printing	5000 scfm	95	120.0	70.0[2]	210	Direct Flame incinerator	1, p. 45
		90	170.0	35.0[3]	240	Carbon adsorption	
	20,000 scfm	95	160.0	35.0[2]	110	Direct flame incinerator	
		90	340.0	110.0[3]	100	Carbon adsorption	
2. Flexographic Printing	5000 scfm	95	120.0	70.0[2]	210	Direct flame incinerator	1, p. 52
	20,000 scfm	95	160.0	35.0[3]	110	Direct flame incinerator	
3. Rotogravure printing	5000 scfm	95	120.0	70.0[2]	210	D.F. incinerator	1, p. 43
		90	170.0	35.0[3]	240	Carbon adsorption	
	20,000 scfm	95	160.0	35.0[2]	110	D.F. incinerator	
		90	340.0	110.0[3]	100	Carbon adsorption	
4. Webb Letterpress printing	5000 scfm	95	120.0	70.0[2]	210	D.F. incinerator	1, p. 48
		90	170.0	35.0[3]	240	Carbon adsorption	
	20,000 scfm	95	160.0	35.0[2]	110	D.F. incinerator	
		90	340.0	110.0[3]	100	Carbon adsorption	

[1] Costs include credit for product or heat recovery. Parentheses indicate net savings.

[2] Includes credit for primary heat recovery.

[3] Includes solvent recovery credited as fuel value of solvent.

Table 5. COSTS OF CONTROL MEASURES FOR SELECTED SOURCES OF EVAPORATIVE HYDROCARBON EMISSIONS

Source/Affected Operation	Facility Size	Control Efficiency %	Capital Cost ($000)	Annualized Cost ($000)	Cost Effectiveness ($/ton)	Control Measure	Reference
1. Organic solvent metal cleaning operations							
- Cold Cleaners							
Low volatility solvent		15%	25	0.5	20	Drainage facility	7, p. 4-7
High volatility solvent		30%	65	(26)	(245)	Drainage facility with mechanically assisted cover.	
- Open top vapor degreasers	Typical	30	0.3	(800)	(365)	Manual cover	7, p. 4-11
		45	6.5	84	25	Refrigerated chiller	
		97	16.0	36	1	Enclosed design	
- Conveyorized degreasers	Typical						
Monorail		50	8.5	(3735)	(260)	Refrigerated chiller	7, p. 4-17
Cross-Rod		50	7.5	(650)	(110)	Refrigerated chiller	
2. Dry cleaning Operations							
- Petroleum plants							
•Neighborhood cleaners dryer, still, misc.		80	16.8	3.5	735	Carbon adsorption	8, p. 48
Filter Muck		90	5.0	1.0	700	Centrifugal separator	
TOTAL			21.8	4.5	730		
•Industrial plant							
Dryer, Still, Misc.		80	71.2	4.4	55	Carbon adsorption	8, p. 4-10
Filter Muck		90	5.2	(3.1)	(127)	Centrifugal separator	
TOTAL			76.4	1.3	15		
- Perchloroethylene plants							
•Coin-op facility		66	7.3	1.8	5450	Carbon adsorption	8, p. 4-18
•Commercial plant		55	2.9	0.1	55	Carbon adsorption	
•Industrial plant		51	7.5	(9.4)	(345)	Carbon adsorption	
3. Cutback asphalt paving		99	N.A.	N.A.	Min.	Substitution of emulsified asphalt	1, p. 32

[1]Costs include credit for product or heat recovery. Parentheses indicate net savings.

[2]The price difference between the two types of liquified asphalt concrete is insignificant.

commercial, and industrial perchloroethylene solvent plants. Finally, the control measure for cutback asphalt paving entails the substitution of emulsified asphalt in order to eliminate evaporative emissions.

C.2.6 Rubber Products Manufacture

In Table C-6 costs are summarized for selected processes in the manufacture of various rubber products. The manufacture of tires and inner tubes represents the largest source of emissions in this category with over 50 percent of the total. Thermal incineration and carbon adsorption are the primary control measures for most sources. However, for the sole attachment operation in shoe manufacturinng, substitution of hot melt adhesives accomplishes the control of emissions at a lower cost than the add-on technologies.

C.2.7 Chemical Manufacturing Processes

Table C-7 indicates the costs for controlling hydrocarbon emissions from selected chemical manufacturing processes. For all but one process, two sets of costs and control measures are given for each level of control efficiency. The difference depends on whether or not the heat from the control device is recovered and utilized. If heat is recovered, equipment has to be added to utilize the heat for process requirements or to generate steam for process requirements. For this option to be feasible, the higher capital costs have to be offset by the savings for the heat or steam recovery. This means that the plant has to have uses for the recovered heat or steam either for in-plant uses or for other plants nearby. Thus, the special circumstances of individual plants dictate the viability of heat or steam

Table 6. COSTS OF CONTROL MEASURES FOR RUBBER PRODUCT MANUFACTURE

Source/Affected Operation	Facility Size	Control Efficiency %	Capital Cost ($000)	Annualized Cost[1] ($000)	Cost Effectiveness ($/ton)	Control Measure	Reference
1. Synthetic Elastomers							
- Tank Farm	20,000 gal	80	18.0	3.6	N.A.	Floating covers	9, p. 4.1.3
- Recovery area	1,000 scfm	90	70.0	27.0[3]	160	Adsorption	9, p. 4.4.3
- Finishing area	15,000 scfm	90	150.0	65.0[2]	35	Thermal incineration	9, p. 4.6.4
2. Tires and Inner Tubes							
- Fabric cementing	5,000 scfm	80	180.0	38.0[3]	90	Adsorption	9, p. 4.14.3
		90	120.0	35.0[2]	65	Incineration	
- Green tire spraying	15,000 scfm	80	320.0	50.0[3]	35	Adsorption	9, p. 4.13.3 (Table 12)
		90	150.0	70.0[2]	45	Thermal incineration	
- Curing operations	25,000 scfm	90	270.0	280.0	2900	Thermal incineration	9, p. 4.10.3
- Undertread cementing	5,000 scfm	90	120.0	40.0[2]	75	Incineration	9, 4.12.2
3. Rubber Footwear							
- Rubber Cementing (Adhesive spraying)	1,000 scfm	90	70.0	19.0[3]	220	Adsorption	9, p. 4.16.2
- Molding operations	25,000 scfm	90	270.0	280.0[2]	2900	Thermal incineration	9, p. 4.10.3 (Table 9)
4. Reclamatory processes	1,500 scfm	90	175.0	56.8	N.A.	Absorption: condenser and scrubber	9, p. 4.19.2
5. Rubber Hose and Belting							
- Fabric Cementing	5,000 scfm	90	120.0	35.0[2]	65	Thermal incineration	9, p. 4.14.3
6. Fabricated Rubber Goods							
- Molding	25,000 scfm	90	270.0	280.0[2]	2900	Thermal incineration	9, p. 4.10.3
- Curing	25,000 scfm	90	270.0	280.0[2]	2900	Thermal incineration	9, p. 4.10.3
- Adhesive spraying	1,000 scfm	90	70.0[3]	19.0[3]	220	Adsorption	9, p. 4.16.2
7. Gaskets, Packing, Sealing							
- Molding	25,000 scfm	90	270.0	280.0[2]	2900	Thermal incineration	9, p. 4.10.3
- Adhesive spraying	1,000 scfm	90	70.0	19.0[3]	220	Adsorption	9, p. 4.12.2
8. Nonferrous Wiredrawing							
- Curing	25,000 scfm	90	270.0	280.0[2]	2900	Thermal incineration	9, p. 4.10.3
9. Tire Retreading							
- Rubber cementing	1,000 scfm	90	70.0	19.0[3]	220	Adsorption	9, p. 4.16.2
- Curing	25,000 scfm	90	270.0	280.0[2]	2900	Thermal incineration	9, p. 4.10.3

[1] Costs include credit for product or heat recovery. Parentheses indicate net savings.

[2] Includes credit for primary heat recovery.

[3] Includes solvent recovery credited as fuel value of solvent.

Table 7. COSTS OF CONTROL MEASURES FOR SELECTED CHEMICAL MANUFACTURING PROCESSES

Source/Affected Operation	Facility Size	Control Efficiency %	Capital Cost ($000)	Annualized Cost ($000)	Cost Effectiveness ($/ton)	Control Measure	Reference
1. Ethylene Dichloride (oxychlorination)	350 x 10^3 TPY	97	2050	207[3]	20	Thermal incinerator, waste boiler and caustic scrubbing	11, Vol. 3 pp. ED-39-40
		97	1500	1075[4]	115	Thermal incinerator and caustic scrubbing	
2. Acrylonitrile	100 x 10^3 TPY	99	1515	190[3]	20	Thermal incinerator and waste heat boiler	11, Vol. 2, pp. AN-32
		99	700	470[4]	45	Thermal incinerator	
3. Ethylene Oxide							
- Air oxidation plant	100 x 10^3 TPY	85	485	38[5]	20	Catalytic incineration	11, Vol. 6, pp. EO-31-32
- Oxygen oxidation plant	100 x 10^3 TPY	85	45	(11)[3]	(5)	Steam generator	
		85	30	24[4]	15	Thermal incineration	
4. Formaldehyde							
- Silver catalyst	50 x 10^3 TPY	80	88	(44)[6]	(275)	Boiler house vent gas burner	11, Vol. 4, p. FS-33
		80	92	22[4]	140	Thermal incinerator	
- Mixed oxide catalyst[7]	50 x 10^3 TPY	93	135	105[3]	155	Thermal incinerator	11, Vol. 5, p. FM-25
		93	108	150[4]	220	Thermal incinerator	

[1]Costs include credit for product or heat recovery. Parentheses indicate net savings.

[2]Costs are updated to 1976 values from reference 11.

[3]Includes credit for steam or heat recovery.

[4]Does not include credit for steam or heat.

[5]Includes heating value credit.

[6]Includes credit for heat recovery as process utilizes waste gas as fuel supplement.

[7]Does not include recycling.

recovery. Existing plants may not have the flexibility necessary to incorporate this option. As a result, some plants may have to employ incineration without any heat or steam recovery, making the annualized costs of control higher than would otherwise be the case.

REFERENCES FOR APPENDIX C

1. "Air Pollution Control Technology Applicable to 26 Sources of Volatile Organic Compounds", Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, May 27, 1977.

2. Radian Corporation, "Background Information on Hydrocarbon Emissions from Marine Terminal Operations", Vol. I, EPA-450/3-76-038, November, 1976.

3. "Control of Hydrocarbons from Tank Truck Gasoline Loading Terminals", Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, May, 1977, Draft.

4. "Control of Volatile Organic Emissions from Gasoline Bulk Plants", guideline document in preparation by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency.

5. Based on internal EPA analysis of comments submitted in response to November 1, 1976, Federal Register notice concerning the proposal of Stage II vapor recovery regulations.

6. "Control of Volatile Organic Emissions from Existing Stationary Sources--Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Ligh-Duty Trucks", Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, EPA-450/2-77-008, May, 1977.

7. "Control of Volatile Organic Emissions from Organic Solvent Metal Cleaning Operations", Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, April, 1977, Draft.

8. "Control of Volatile Organic Emissions from Dry Cleaning Operations", Office of Air Quality Planning and Standards, U.S. Environmental Proection Agency, April, 1977, Draft.

9. Monsanto Research Corporation, "Identification and Control of Hydrocarbon Emissions from Rubber Processing Operations", EPA Contract No. 68-02-1411, Task 17, March, 1977.

10. "Control of Organic Solvent Emissions from Adhesive Usage During Shoe Manufacture", guideline document in preparation by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency.

11. Air Products and Chemicals, Inc., "Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry", Volumes 2-6, EPA-450/3-73-006.

12. "Control of Volatile Organic Emissions from Existing Stationary Sources--Volume I: Control Methods for Surface Coating Operations", Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, EPA-450/2-76-028, November, 1976.

13. "Control of Volatile Organic Emissions from Existing Stationary Sources -- Volume V: Surface Coating of Large Appliances," Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, EPA-450/2-77-034, December, 1977.

14. "Control of Volatile Organic Emissions from Existing Stationary Sources--Volume III: Surface Coating of Metal Furniture", Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, EPA-450/2-77-032, December, 1977.

Appendix D

Analysis of Costs for the Federal Motor Vehicle Control Program

Emission Control Technology Division
Office of Mobile Source Air Pollution Control
U.S. Environmental Protection Agency
Ann Arbor, Michigan

APPENDIX D

The purpose of this appendix is to present the EPA cost estimates for the FMVCP based on the most recent information available to the EPA technical staff. The cost of the following programs will be discussed in detail:

- Light-Duty Vehicles
- Light-Duty Trucks
- Heavy-Duty Vehicles
- Motorcycles
- Aircraft

It should be recognized that the cost estimates provided in this document are all in 1978 dollars and are subject to future revision. However, due to the need for these numbers in the immediate future, the best, currently available cost estimates have been used.

Table 1 presents a summary of the FMVCP costs.

I. Light-Duty Vehicles

No estimates of the cost of the light-duty vehicle program have yet incorporated all of the most recent information. Such an estimate will be developed in the following discussion.

I.A. Initial Cost of Emission Control Systems

The predominant emission control system which is expected to be in production for model year 1987 (and emission standards of 0.41 HC, 3.4 CO, 1.0 NOx) is a three-way plus oxidation catalyst system using feedback carburation, exhaust gas recirculation and air injection. Some vehicles, particularly those at inertia weights of 3,000 pounds and below with low power to weight ratios, could be certified using current

Table 1

Cost Summary
(In Billions of 1978 Dollars)

Source	Control	Gaseous Emissions for HC Control	Unleaded Fuel for HC Control	Evaporative Emissions for HC Control	Altitude for HC Control
I.LDV		-0.63*-0.75	.59-.86	.272-.322	.025-.473
II. LDT		.38-.800	.30-.43	included in LDV estimate	.10-.189
III. HDV		.532	Included under gaseous emissions	.016	
IV. MC		.046			
V. AC		.025			

*Note: the negative sign indicates a net savings

oxidation catalyst technology. The initial cost to the consumer of these systems are $158-162[2] for a vehicle using an oxidation catalyst system and $269-285[2] for a vehicle using a three-way plus oxidation system. Both ranges of cost are compared to uncontrolled vehicles.

To provide estimates which are on the high side, only the $285 number will be considered further. But first, the $285 figure will be fully substantiated.

The $285 figure was generated by the EPA technical staff by combining the costs of emission control components as provided in reference 3. Most of the costs used by the staff were taken directly from this reference. One important exception is the cost of an electronic control unit. A lower cost was used than the one provided by reference 3 for three reasons. First the EPA technical staff is aware of replacement parts (which are normally much more expensive than OEM parts) that sell for about the same price as that quoted by reference 3. And second, the ECU cost estimated in reference 3 is for a unit controlling more functions than assumed by the technical staff, and finally, the cost assumed in reference 3 is for analog components not for large scale integrated (LSI) components as will be used in 1987.

The precise component costs used by the technical staff are shown in Table 2.

The component costs in reference 3 were generated by Mr. LeRoy Lingren of Rath and Strong, Inc. Mr. Lingren has been recognized as an

Table 2

Cost of Components in a Three-Way Plus Oxidation Catalyst System

Component	Cost in '78 Dollars	
	Min.	Max.
Throttle Position Sensor	-	2
PCV valve	1	1
HEI (less breaker point distributor)	7	7
TVS (spark)	-	2
Electric choke	1	1
EFE	4	4
ECR (backpressure)	7	7
TVS (EGR)	-	2
Stainless steel exhaust pipe (less steel pipe)	9	9
Air injection system	30	30
Air switching system	2	2
Feedback carburetor (less open loop carburetor)	8	8
Three-way plus oxidation catalyst	157	157
ECU	30	30
O_2 sensor	3	3
H_2O temp sensor	-	2
Inlet air temp sensor	-	2
Engine speed sensor	-	2
Crank angle position sensor	-	2
EGR pintle position sensor	-	2
Evaporative system	10	10
TOTAL	269	285

expert in the field of cost of emission control systems for a number of years. In addition to his efforts for EPA, he has done similar work for the National Academy of Sciences (see reference 4).

Now, assuming the cost of the 1987 emission control system to be $285, a judgment must be made concerning what fraction of that cost should be allocated to HC control as opposed to CO and NOx control. Two estimates of that fractional cost were developed by the technical staff. The high estimate is $200. A more reasonable estimate is $285/3 (for control of 3 pollutants) or $95.

Assuming 10 million cars are sold per year, the annual cost due to initial cost increases would be:

$$10 \times 10^6 \text{ (vehicles sold per year)} \times (\$95 \text{ to } 200 \text{ per vehicle}) = \$0.95 \text{ to } 2.00 \times 10^9$$

I.B. Maintenance Costs

The items in Table 3 were considered to be the changes in maintenance between uncontrolled vehicles and 1987 model year vehicles.

The costs in Table 3 are considered by the technical staff to be a case of minimal savings as the prices assumed for spark plus changes and point/condensor changes are probably too low. The increase in oil change intervals, which is at least in part attributable to the use of unleaded fuel, is not considered. Also O_2 sensor change intervals may be more than 30,000 miles by 1987 as that interval is being used or exceeded by some production vehicles already. The $50 miscellaneous cost for repair of emission control systems is in addition to that amount for repairs attributable to inspection and maintenance programs.

It is then assumed that a $5 per year savings in maintenance cost will be accumulated by each vehicle on the road (110×10^6 vehicles) for a total savings of $\$0.55 \times 10^9$ per year.

Table 3

Maintenance Changes Over 100,000 Miles

Maintenance	Total Cost of Maintenance	Cost Related to HC Control
Change O_2 sensor 3 times	3 x 15 = $45	1/3 x 45 = $15
Miscellaneous emission system repairs	$50	1/3 x 50 = $17
Save 5 plus changes	5 x 10 = $(-)50	1/2 x (-50) = $-25
Save 10 point/condenser changes	10 x 10 = $(-)100	1/2 x (-100)=$-50
Save 1 muffler change	$(-) 20	1/3 x (-20) = $-7
Total	$(-)75 per 10 years	$(-)50 per 10 years

I.C. Differences in Fuel Economy

Figure 9 of reference 5 shows the composite economy of 1978 California vehicles (which meet a 0.41 HC standard) to be about 7 or 8% better than that of uncontrolled vehicles at a constant weight mix. It also can be seen from Figure 9 of reference 5 that current Federal vehicles achieve 19 or 20% better fuel economy than their uncontrolled counterparts. While it could be argued that fuel economy will continue to improve until 1987, even with respect to Federal vehicles, the technical staff hass chosen to further consider only the 7% benefit. This value represents only a minimal fuel savings.

To determine the annual dollar savings due to improved vehicle fuel economy in 1987, some value of the fuel economy must be assumed. Two such values were chosen, and those values are 17.0 and 25.0 miles per gallon. These values represent a 7% improvement when compared to 15.9 and 23.4 miles per gallon respectively.

Assuming that all vehicles on the road (110×10^6 vehicles) travel 10,000 miles per year (somewhat low) and that gasoline costs 70¢/gal (again this may be low for 1987) the total savings ranges from 2.1 to 3.1 billion dollars. For HC control only (i.e., divide by 3) this would be a savings of 0.72 to 1.03 billion dollars.

I.D. Summary of Gaseous Emissions

A range of cost attributable to LDV gaseous emission control was obtained by summing the initial cost of emission control systems, maintenance savings, and savings in fuel economy.

The minimum cost of the program is calculated as follows:

$$[.95 - .55 - 1.03] \times 10^9 = -\$0.63 \times 10^9$$

The maximum cost of the program is then:

$$[2.00 - .55 - 0.7] \times 10^9 = \$0.75 \times 10^9$$

I.E. The Use of Unleaded Fuel

Unleaded gasoline is now 4 to 5¢/gal more expensive than regular gasoline. This trend is partially due to a slightly higher refining cost of unleaded fuel and partially because of pricing strategies of gasoline retailers. Unleaded fuel is currently the "lower volume" seller, but by 1987 unleaded fuel will be the "high volume" product as demand for regular gasoline will be greatly reduced.

If the cost differential between regular and unleaded gasolines is heavily influenced by production volume, regular may be more expensive than unleaded by 1987. However, in the interest of keeping the calculations in this text conservative, a 4¢/gal penalty is assumed.

Again for 110 million cars going 10,000 miles per year with fuel economy ranging from 17 to 25 miles per gallon, the total penalty would be 1.76 to 2.59 billion dollars. For HC control only, the penalty is 0.59 to 0.86 billion dollars.

I.F. Evaporative Emissions (Includes LDV and LDT)

Control of evaporative emissions has evolved from a 2 gram/test canister standard to a 6 gram/test SHED standard in 1978 to a 2 gram/test SHED standard for 1981. In 1974 the cost to implement the 6 gram/test SHED regulations was estimated[6] to be 82 million dollars per year. The 2 grams/test SHED regulations (for 1981) are to cost [7] an additional 12 to 62 million dollars per year.

A good estimate for the cost of going from uncontrolled to the 2 gram/test canister standard was not available. So an estimate of $10 per vehicle[8] was added to each new vehicle. The number of new vehicles was assumed to be 14 million per year.

Thus, the total cost of LDV and LDT evaporative emission standards was calculated as follows:

$.082 x 10^9 x $(1.1)^4$ (to go to '78 dollars) + [.012 to .062 x 10^9]

+ $10 x 14 x 10^5 (vehicles per year) = $0.272 to 0.322 x 10^9

I.G. Emission Control at Altitude

Emission control at altitude is not required for model years 1979 through 1980 as a result of the 1977 Clean Air Act Amendments. Altitude regulations may be in force again by the 1981 model year. The final form of these regulations has not yet been determined, and a number of options for emission control at altitude during the 1981 and subsequent model years are under consideration. In addition the Clean Air Act requires stringent altitude controls beginning with the 1984 model year. Thus, the program cost can only be estimated within a fairly wide range. That range is from $0.050 to 0.945 x 10^9 as seen in references 9 and 10 respectively. To consider only HC control the dollar amounts were cut in half to $0.025 to 0.473 x 10^9.

II. Light-Duty Trucks

II.A. Initial Cost of Emission Control Systems

Initial costs of emission control systems for light-duty trucks were assumed to be the same as for light-duty vehicles. That is $95 to 200 for HC control compared to uncontrolled trucks. Four million LDT's were assumed to be sold in 1987. The total cost then is:

($95 to 200) x 4 x 10^6 (sales) = $0.38 to 0.800 x 10^9

II.B. Maintenance Costs

To be conservative, no maintenance savings were credited to light-duty trucks.

II.C. Difference in Fuel Economy

Fuel economy savings were also not credited to light-duty trucks, even though savings are expected.

II.D. Use of Unleaded Fuel

The dollar penalty for light-duty vehicles was reduced by the factor of 0.4 ($4 \times 10^6 / 10 \times 10^6 = 0.4$) to account for differences in population and increased by the consideration of the difference between LDT and LDV fuel consumptions. (The DOE gasoline volume model predicts* the ratio of LDV to LDT fuel economy in 1985 to be 1.25).

The cost is calculated as follows:

$(\$0.59 \text{ to } 0.86 \times 10^9) \times 0.4 \times 1.25 = \$0.30 \text{ to } 0.43 \times 10^9$

II.E. Emission Control At Altitude

This was estimated to cost 40% of the cost of LDV emission control at altitude. The 40% is to correct for differences in annual sales between LDT and LDV.

III. Heavy-Duty Vehicles

III.A. Gaseous Emissions

The total cost of the proposed 1983 and subsequent model year heavy-duty vehicles emission standards (for 90% reductions of HC and CO) was found to be 2.5065 billion dollars in reference 11 for 1983 to 1987.

---

*Personal communication between K. Hellman of EPA and B. McNutt of DOE on October 26, 1978.

This cost includes first cost and maintenance for hardware to comply with the emission standards for 1983 and subsequent model years, certification testing, modifications to facilities to permit testing, inspection and maintenance programs for such vehicles, and the switch to unleaded fuel for gasoline-fueled vehicles. Fuel economy of heavy-duty vehicles was assumed to remain constant.

An approximate annual cost for gaseous emission control was calculated as follows:

$$\frac{\$2.5065 \times 10^9}{5 \text{ years}} = \frac{\$0.501 \times 10^9}{\text{year}}$$

This number includes an unleaded fuel cost differential which is 5¢/gal and is even more conservative than the 4¢/gal assumed for LDV's.

It should be noted that CO control was not separated from HC control in the previous estimate. Since the cost of going from uncontrolled heavy-duty engines to pre-1983 engines was not readily available, that amount was considered to be roughly equal to (and negated by) the portion of the $\$0.501 \times 10^9$ which would be attributed to CO control.

As a very rough estimate of the cost of the standards for 1985 which may require 90% HC and CO control and 75% NOx control, a cost of $150 was assumed to be added for every gasoline and Diesel-fueled vehicle. Annual sales were assumed to be one half million. Thus the incremental cost of this phase was estimated to be:

$\$150 \times 0.5 \times 10^6$ (vehicles) = $\$0.075 \times 10^9$ per year

No change in fuel economy is expected. The total cost of the HDV gaseous emission control is:

$$\$.507 \times 10^9 + \frac{.075 \times 10^9}{3} = \$.532 \times 10^9 \text{ per year}$$

III.B Evaporative Emissions

Reference 12 states that the cost of heavy-duty evaporative emission control for the 1982 to 1986 model years will be $\$56 \times 10^6$. This figure is currently being reevaluated. Our best estimate is that this amount will not exceed $\$80 \times 10^6$. So based on the latter estimate, the cost per year would be:

$$\frac{\$80 \times 10^6}{5 \text{ years}} = \frac{\$16 \times 10^6}{\text{year}} = \frac{\$.016 \times 10^9}{\text{year}}$$

IV. Motorcycles

Reference 13 indicates that the cost to the consumer of the 1978 and 1980 motorcycle emission standards will be 104.3 million dollars* over the 1978 to 1982 timeframe (including fuel consumption). Assuming these to be 1976 dollars, the approximate annual cost for HC control would be:

$$\frac{\$104.3 \times 10^6 \times (1.1)^2 \text{ (to go to 78 dollars)} \times 1/2 \text{ (for HC only)}}{5 \text{ years}}$$

$$= \frac{\$1.26 \times 10^7}{\text{year}} = \frac{\$.013 \times 10^9}{\text{year}}$$

Motorcycle emission standards for the 1983 to 1984 model years and the 1985 and subsequent model years have not yet been proposed. However, the cost of these regulations may be estimated from figures 25 and 28 of reference 13.

The incremental cost of the 1985 standards based on those figures is roughly estimated to be $100 (in 1978 dollars) per motorcycle over uncontrolled. This represents a $150 first cost minus a $50 fuel savings. If there are one million motorcycles sold per year, then the cost of this program would be about:

$\$100 \times 10^6$ (motorcycles) = $\$.100 \times 10^9$ per year

For HC control only, the cost is assumed to be one third of the 0.1 billion dollars or .033 billion dollars as HC and CO could be reduced by 90% and NOx could be reduced by 75% for 1985.

The total cost of the motorcycle program for HC control would then be:

($[.013 + .033] x 10^9 = $0.046 x 10^9 per year

V. Aircraft

A complete discussion of the cost of proposed aircraft regulations is presented in reference 14. The cost of the program was determined as shown in Table 4.

Table 4

Cost of the Aircraft Program

Costs Summed in '76 Dollars	Location in Reference 14
$66,400 \times 10^3$	Table 8, p. 20
$5,894 \times 10^3$	Table 8, p. 20
$114,443 \times 10^3$	Table 9, p. 21
$228,600 \times 10^3$	Table 10, p. 22
$267,078 \times 10^3$	Table 10, p. 22
36.7×10^6	Table 11, p. 24
-0.7×10^6	Table 12, p. 25
-88.7×10^6	Table 13, p. 26

629.7×10^6 for 15 - 18 years

The total of $\$629.7 \times 10^6$ is in 1976 dollars and is for a total of 18 years of HC and CO control and 15 years of NOx control. Fuel consumption effects are included.

Approximate annual cost of the program for HC was calculated as follows:

$$\frac{[\$629.7 \times 10^6 \times (1.1)^2 \text{ (to go to '78 dollars)}] \times 1/2 \text{ (for HC only)}}{15}$$

$$= \frac{\$2.539 \times 10^7}{\text{year}} = \frac{\$.025 \times 10^9}{\text{year}}$$

The $\$.025 \times 10^9$ per year is on the high side as three pollutants are controlled for 15 years and two pollutants for an additional three. In any case the aircraft program is small contributor in terms of total program cost.

References

1. Federal Register, June 22, 1978 (43 FR 26962-26985).

2. "Analysis of Technical Issues Relating to: California's Request for Waiver of Federal Preemption with Respect to Exhaust Emission Standards and Test Procedures ofr 1981 and Subsequent Model Years Light-Duty Vehicles", Environmental Protection Agency, Emission Control Technology Division, March, 1978, p. 21.

3. Cost Estimations for Emission Control Related Components/Systems and Cost Methodology Description, EPA-460/3-78-002, prepared by LeRoy H. Lingren of Rath and Strong, Inc., March, 1978.

4. Manufacturability and Costs of Proposed Low-Emissions Automotive Engine Systems, Consultant Report to the: Committee on Motor Vehicle Emissions, Commission on Sociotechnical Systems, National Research Council, Sept., 1974.

5. "Light Duty Automotive Fuel Economy Trends Through 1976," SAE Paper 780036, J.D. Murrell, Environmental Protection Agency, Feb.-Mar., 1978.

6. "Revised Evaporative Emission Regulations for the 1978 Model Year," Environmental and Economic Impact Statement, Environmental Protection Agency.

7. "Revised Evaporative Emission Regulations for 1981 and Later Model Year Gasoline-Fueled Light-Duty Vehicles and Trucks," Environmental and Economic Impact Statement, Environmental Protection Agency, Aug. 7, 1978.

8. Investigation and Assessment of Light-Duty Vehicle Evaporative Emission Sources and Control, Report No. EPA 460/3-76-014.

9. "Draft Environmental and Economic Impact Statement for 1981-1983 High Altitude Emission Standards", Environmental Protection Agency, Sept. 29, 1978, Table III, 1977 approach with I/M.

10. "Draft Report to Congress in Response to Section 206(f)(2) of the Clean Air Act as amended in August, 1977", Environmental Protection Agency as of Oct. 27, 1978.

11. "Revised Gaseous Emission Regulations for 1983 and Later Model Year Heavy-Duty Engines," Draft Environmental and Economic Impact Statement, Environmental Protection Agency, as of Oct. 26, 1978.

12. "Draft Environmenal Impact Statement for Gasoline-Fueled, Heavy-Duty Vehicles - Notice of Proposed Rulemaking", Environmental Protection Agency, as of Oct. 26, 1978.

13. "Exhaust and Crankcase Regulations for the 1978 and Later Model Year Motorcycles", Environmental and Economic Impact Statement, Environmental Protection Agency, Dec. 14, 1976.

14. "Cost-Effectiveness Analysis of the Proposed Revisions in the Exhaust Emission Standards for New and In-Use Gas Turbine Aircraft Engines Based on EPA's Independent Estimates", Technical Support Report for Regulatory Action, Richard S. Wilcox and Richard W. Munt, Environmental Protection Agency, Dec. 14, 1976.

Appendix E

COST/EFFECTIVENESS OF INSPECTION AND MAINTENANCE PROGRAMS

Emission Control Technology Division
Office of Mobile Source Air Pollution Control
U.S. Environmental Protection Agency
Ann Arbor, Michigan

Appendix E

COST/EFFECTIVENESS OF INSPECTION AND MAINTENANCE PROGRAMS

I. Direct Costs and Benefits

The following costs and benefits are associated with an I/M program.

1. The cost of program implementation is assumed to be negligible by 1987, on the premise that an annual I/M program begins in 1982.

2. The cost of a program's day-to-day operation is assumed to be covered by a $5/car inspection fee. This is the fee for an I/M sticker in Oregon's I/M program. The cost of inspection is expected to vary somewhat from program to program, but inspection fees in currently operating I/M programs are in the neighborhood of $5.

3. The cost of repairing failed vehicles was estimated from the two latest data sets available for 1975-1977 model year cars. The first data set is the Portland Study, which is a large scale test program designed to evaluate the effectiveness of an operational I/M program (Oregon's I/M program). The second data set is the California Air Resources Board's Light Duty Vehicle Surveillance Test Program, Second Series CVS [LDVSP-II], in which cars failing the idle portion of a loaded mode test were maintained by CARB in a manner expected to be seen in the field. A $50 limit on repair costs was also imposed. The data are summarized below.

California-12 cars (all catalytically equipped) - Avg. cost = $16.45

Portland-99 cars (most catalytically equipped) - Avg. cost = $23.35

A conservative best estimate of repair costs due to I/M is $15, since voluntary owner repairs will eventually be made to many of the items which are performed to pass an I/M test.

4. The cost to the consumer in time/gas is ignored in this analysis.

5. The benefit to air quality from an I/M program which employs an idle test is estimated on the basis of EPA surveillance data and projections of these data to future years, and a simulation of the I/M process. The computer program MOBILE1 (available from EPA, Ann Arbor, Michigan) was used to facilitate the calculations. Assuming that an I/M program begins in 1982 with an initial failure rate of 30%, the reduction in hydrocarbons (gm/mi) is approximately 30%.

6. The improved quality of repair which the entire I/M fleet should experience is ignored in this analysis.

7. The potential for longer vehicle life due to better and more regular quality of repair is ignored.

8. The average improvement in urban fuel economy for repaired vehicles was estimated on the basis of the Portland and CARB data sets discussed under item (3). The data are summarized below.

CARB	- 12 cars	- 4 percent improvement
Portland	- 99 cars	- 1 percent improvement

A best estimate is considered to be 1.5%.

II. Cost of I/M per Vehicle

On a per vehicle basis, the costs of I/M are calculated on the basis of estimates presented in the previous section and also on the basis of the following assumptions:

1. A gasoline price of $.70 per gallon in current dollars;
2. A fleetwide average of 10,000 miles per year per vehicle;
3. An average fleetwide fuel economy without I/M of 25 miles per gallon;
4. A failure rate of 30 percent for the program in 1987.

Thirty percent of the vehicles included in the program will fail the inspection and thus will have to be repaired. The cost per repaired vehicle will include the inspection fee ($5) and the repair cost ($15) minus the savings resulting from improvement in fuel economy ($4.20). The net cost will be approximately $15.80 per repaired vehicle. The cost for the 70 percent of the vehicles that pass the test will amount to only the $5 inspection fee.

Only half of the cost of an I/M program is attributable to HC control since CO is also being controlled. Existing programs are equally stringent for CO as for HC, hence as many failures result from CO as they do from HC.

III. Cost-effectiveness of I/M

The average cost per vehicle will represent a weighted average of the cost per repaired vehicle and the cost per passed vehicle, as follows:

($15.80 per repaired vehicle) x (.3) +($5 per passed vehicle) x (.7) = $8.24 per vehicle

Since only half of this cost is attributable to HC, the cost per vehicle will be $4.12 for HC control.

The tons of exhaust eliminated per vehicle by I/M based on 30 percent control will be: $(1.98 \text{ gm/mi}) \times (.3) \times (10{,}000 \text{ mi/yr}) \div (908{,}000 \text{ gm/ton}) = 6.5 \times 10^{-3}$ tons/yr

The cost-effectiveness is calculated by dividing the average cost per vehicle by the tons of HC eliminated: $\frac{\$4.12}{6.5 \times 10^{-3} \text{ tons}} = \$635$ per ton